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STRP Report 13

Accommodating Mobility-Aids on Canadian Low-Floor Buses Using the Rear Facing Position Design:

Experience, Issues, and Requirements

a project managed by
un projet dirigé par

cuta actu

Canadian Urban Transit Association
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Prepared by:

Rutenberg Design Inc.

November 2000

CUTA Mission Statement

CUTA is the association of providers of urban transit services, suppliers and related organizations in Canada. Its mission is to promote the role of urban transit in enhancing mobility, and to support its members in the fulfilment of their mandate.

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Accommodating Mobility-Aids on Canadian Low-Floor Buses Using the Rear-Facing Position Design: Experience, Issues, and Requirements

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Abstract

This report is a follow-up to a previous study on *Urban Transit Bus Accessibility Considerations* (STRP 10), which first introduced the European concept of the Rear-facing Position Design concept. This concept enables persons using mobility-aids to position themselves safely within a low-floor urban bus, with their back and head against a load-bearing panel. It allows for complete independence of the wheelchair passenger to ride without the use of hooks or belts, adapts to most wheelchair/scooters sizes and types, does not require the assistance of the operator, and provides a level of safety equivalent to that afforded to other bus passengers, but the wheelchair passenger must face to the rear.

The forward facing belt systems, mandated in the US, provide a high level of safety, but also require that the operator must deploy hooks and belts for the securement of the wheelchair, and another set of belts for restraining the occupant. The wheelchair passenger depends completely on the operator's assistance to ride a transit bus, and is the only passenger wearing a seat/shoulder belt. Boarding and securement is a time-consuming, awkward, and sometimes degrading experience. Canadian systems have adopted in some cases modified versions of the US systems that are less onerous, but do not accommodate all wheelchair types and still require operator assistance.

Currently, most European transit systems, and an increasing number of Canadian ones, have implemented the Rear-facing Position Design on their low-floor buses. The report documents current experience with the Rear-facing Position Design in both European and Canadian transit; explores a variety of implementation issues; and identifies requirements and conceptual design considerations for further implementation.

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EXECUTIVE SUMMARY

This project describes the results of an investigation into the present practises of the use of wheelchair securements for mobility aids on low floor buses. There are mainly two approaches being pursued, one is the forward facing wheelchair/occupant protection system used in the US and required by ADA legislation, and the other, the rear facing position with protection against sharp braking, acceleration and cornering.

Both systems have their consequences in regard to the level of safety provided, the degree of independence for the wheelchair passenger, and the effects on bus operator efforts and responsibility.

The forward facing belt systems used in the US provide a high level of safety, but also require that the operator must deploy hooks and belts for the securement of the wheelchair and another set of belts for restraining the occupant. The wheelchair passenger must face forward and is by law mandated to accept the securement system. The wheelchair passenger depends completely on the operator's assistance to ride a transit bus if unable to deploy belts him/herself, and is the only passenger wearing a seat/shoulder belt. Boarding and securement is a time-consuming, awkward, and sometimes degrading experience. Canadian systems have adopted in some cases modified versions of the US systems, that are less onerous, but do not accommodate all wheelchair types and still require operator assistance.

The rear facing position system originated in Europe and is in use now in many European countries as well being implemented by many Canadian transit operations. It provides the same level of safety afforded to all other seated bus passengers, allows for complete independence of the wheelchair passenger to ride without the use of hooks or belts, adapts to most wheelchair/scooters sizes and types, and does not require the assistance of the operator, but the wheelchair passenger must face to the rear. The rear facing is not an issue in Europe, because transit buses have always had other rear facing seats. In North America rear facing is not common in transit buses. It is nevertheless accepted in trains, and subways.

Accident rates in North America and Europe for transit buses are extremely low. According to statistics, transit buses are much safer to use than any other surface transportation. Research done in Germany and France also proved that unsecured wheelchair passengers when facing to the rear with their back and head against a load bearing panel, provide a safe way of transportation on transit buses.

Although in Canada a modified forward facing position is still used by some operators, various other transit systems are experimenting with and implementing the rear facing system. They include Hamilton, Ottawa, Montreal, Grand River, Victoria and the smaller municipalities in British Columbia.

This report presents the results of investigations for the accommodation of mobility devices on European and Canadian low floor buses using the rear facing position, and discusses experience, issues and requirements for the Canadian context.

1. INTRODUCTION

With the introduction of low floor buses and the increasing cost and demand of paratransit, there has been a renewed interest in making conventional buses more accessible to people with disabilities. Boarding and securement technology are two of the most important considerations in achieving this goal of wider accessibility. However, the impact of these technologies on the regular operation of buses needs also to be examined. For small buses in Canada and all buses in the USA, stringent standards exist that require securement of passengers with mobility aids. These standards are in stark contrast with studies and experience in Europe where no securement system is required at all for passengers in wheelchairs on transit buses.

To further understand the complexities involved in providing safe and efficient accessibility, the Canadian Urban Transit Association (CUTA) conducted, as part of its Strategic Transit Research Program (STRP), a study of Urban Transit Bus Accessibility Considerations (STRP 10 - August 1995). This study investigated the most common boarding and securing technologies currently being used in North America for wheelchair and scooter users, as well as the standards that require them, and examined the European "rear facing position" approach. The STRP study provided some recommendations that transit systems should consider when increased accessibility on standard size buses is desired. The study also suggested that there are problems with the location of wheelchair positions at the front of the bus, as well as with the stowage and operation of securement systems, which requires a second person to deploy and disconnect belts and hooks, and makes the person in the wheelchair more dependent.

Since its beginning in 1993, CUTA's STRP study stimulated considerable interest in the potential application of the "rear facing position" concept in Canadian low-floor buses. This concept consists of an open area along the side of a bus wall, with a load-bearing head and backrest, and an aisle-facing support. In this configuration, the person in the wheelchair faces to the rear, so that in cases of severe deceleration, the person in the wheelchair backs into and is protected by, the load-bearing head and back rest. The aisle-facing support prevents the wheelchair from swerving/tipping into the aisle. The advantage of the concept is that it accommodates almost all wheelchair and scooter types and sizes and it does not require the use of belts or hooks, thus providing total independence to the wheelchair user.

Given the high level of interest among transit systems in Canada with respect to the use of the rear facing position design, CUTA had decided to explore in greater detail experiences in Europe and Canada with rear facing position designs, and the issues related to its use in the Canadian context.

2. CURRENT EXPERIENCE WITH SECUREMENTS IN NORTH AMERICA

2.1 Canadian operations

In Canada, most transit operators are in the process of introducing low floor buses in their fleets. Low floor buses have significantly increased the level of accessibility for people using wheelchairs and scooters, but several issues must be addressed: vehicle design, wheelchair manoeuvrability, securement and placement, operator awareness and training, and bus stop design.

The securement issue represents one of the major concerns and includes: forward versus rear facing of wheelchair passengers; independent or assisted use of securements; and adaptation for different wheelchair sizes and designs.

In Canada, some transit operators use a forward facing position similar to that in the United States or a modified version of this. However, transit operators in Hamilton, Grand River, Victoria, Ottawa and Montreal are experimenting with and have implemented rear facing positions, located either at the front behind the wheel wells, or near the centre door.

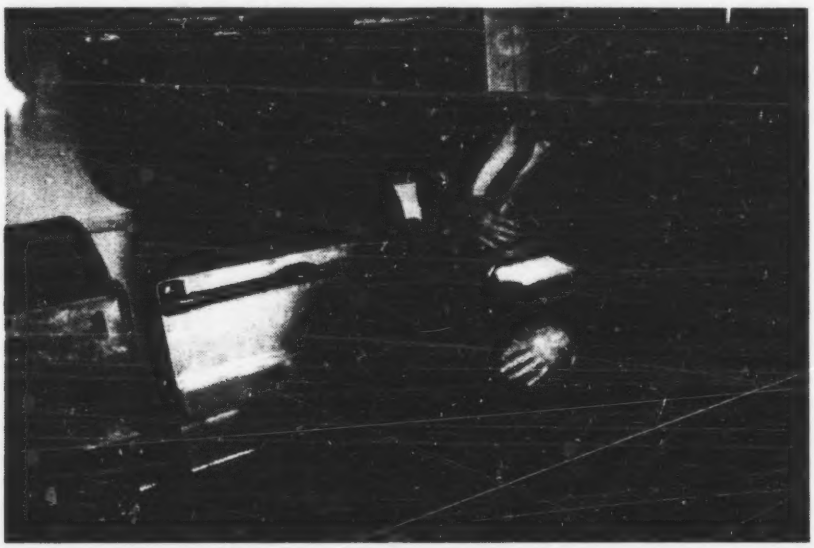

Fig. 1 Modified forward facing securement - two rear belts and wheel stop - used by BC Transit in Victoria

Forward facing Securement

When this system was introduced on conventional public transit vehicles in the late 1970s, it was simply a technology transfer of the securement system then in use on small paratransit services. Until recently, it has continued to be the norm for transit systems in Canada.

The forward facing system consists of two components: the wheelchair securement and the occupant restraint. The wheelchair securement ties the wheelchair to the vehicle, either by using two rear and two front belts or two rear belts with a wheel stop. The occupant restraint provides a lap and a shoulder belt. An occupant restraint is available in many transit vehicles, but its use is not mandatory. Forward facing positions are typically located at the front of the bus behind the wheel wells. The wheelchair user accesses the bus through the front door and faces the front of the vehicle like all other passengers.

There are three main types of forward facing systems in use:

1. four belts: two for the front, two for the rear (ADA compliant system);
2. two rear belts with angled wheel stop for manual and power chairs, with one additional front belt for scooters;
3. wheel rim lock combined with one rear retractable belt.

The forward facing system has served the needs of many wheelchair users, but it has a number of disadvantages:

- Assistance is required to secure the wheelchair and to deploy the occupant restraint. Assistance from the bus operator disrupts the transit operation and involves risk of employee injury. Physical operator-passenger contact is awkward and a sensitive issue.

- The system is not readily adaptable to the wide range of wheelchairs in use, particularly scooters. Extra belts are required, thus increasing the complexity of the securement process.

- Many wheelchairs are not structurally capable of being secured by belts or do not have specific attachment points, thus they could be damaged in an accident or severe braking situation, causing injury to the user.

- The belts are difficult to keep clean and to store. Hanging loose onto the floor, they can be a hazard to other passengers.

- In conventional transit systems, the infrequent use of belt systems and the wide range of wheelchair designs may result in incorrect securement practices.

- Securing the wheelchair is time-consuming and physically demanding for the operator or attendant.

The advantages of the forward facing system include:

- Wheelchair users face forward, the same as other passengers. This allows them to watch for their destination, to signal the operator to stop, and to brace themselves against sudden movements.

- The belt system anchors the wheelchair to the vehicle, providing wheelchair passengers with stability when the vehicle is moving.

Alternative forward facing securement systems using other mechanical concepts have been, or are being, researched in the United States in the hope of developing a universal securement system (e.g., the MLS docking system, the Cleveland Clinic harness). However, they have not yet proven effective, largely because of the wide range of wheelchair designs and/or the modifications that are required for mobility aids, which users dislike.

Rear facing Position

The STCUM in Montreal was one of the first operators expressing considerable interest in the potential of using this concept in the new Nova Bus low-floor vehicles they were acquiring. As a result an initial study was carried out in 1994 to verify if front or centre door boarding was the most effective method to facilitate access for persons using wheelchairs. Following this, preliminary tests were undertaken to verify if a rear facing position design, located near the centre door would be a feasible solution. The development of the new low-floor buses for the STCUM has proceeded along these lines.

In Ontario, a study entitled "Implementation of Low-Floor Urban Transit Buses" examined a number of issues related to safety, securement, etc. The study also addressed the wheelchair securement issues including the rear facing position design. Interest has lead to initial demonstrations and present implementations of the rear facing position design in Hamilton, Grand River Transit (former Kitchener and Cambridge Transit), and Ottawa. There are a variety of rear facing applications used by these operators, depending on their operation, vehicle design, and infrastructure interface. Some operators use rear facing positions on opposite sides of the bus, others a tandem configuration at road side or at curb side. Ramp types vary from sliding to flip ramps at the front or centre door. Aisle stanchions or lateral wall mounted belts are typically used to prevent wheelchairs or scooters from tipping or moving into the aisle. Wheelchair compartments are usually outfitted with flip seats along the bus wall or with one flip seat forming part of the back panel. All compartments have a separate stop request button to alert the operator, but there is a lack of visual announcements for the next stop for rear facing passengers in many buses. Except for some operations, no satisfying answer has been found to provide courtesy seating for seniors without creating conflict with the location for wheelchairs. A few operators have a separate courtesy seat near the front door facing the operator.

In the late 90's, BC Transit in Victoria introduced rear facing positions for their 9.3 m (30 feet) and 10.5 m (35 feet) Dart low floor buses. On order are also low floor double-decker buses with a planned combi design for a wheelchair position. This position provides a choice for a passenger in a wheelchair to use either a forward facing position with securement belts or the rear facing orientation without belts.

In Canada, the CAN/CSA D409-92 standard was developed to protect passengers using mobility aids when being transported in small vans, and special paratransit vehicles. But since the introduction of low floor buses in urban transit and the tendency to make public transit accessible for persons with mobility impairments and in particular to persons using mobility aids, discussions in Europe and North America have focused on several major issues. This lead to draft revisions proposed to D 409 for large buses in June of 2000. The proposals made in this document are based on present practice and research which has been undertaken in Germany, the UK and Canada in the last decade. This research suggests:

- that G forces on large transit buses with a GVWR of 7,000 kg or over are much smaller than on lighter vehicles e.g. small buses, vans, special vehicles, due to larger masses and lower operating speeds;
- that on large transit buses, mobility aid users can travel safely in the rearward facing position under typical operating conditions without securement systems, provided that adequate provision is made for the location and positioning of their mobility aids, and
- that this standard is further supported by evidence from transit operators on how well the practices have worked on large accessible transit buses both in Europe and in Canada.

The challenges facing operators in the future include operational, technical, infrastructure and legislative issues.

- Operational: wheelchair positions, seat capacity, courtesy seat, fare payment, service door location, operator responsibility;
- Technical: wheelchair securements, stanchions, ramp type, door size, next stop announcements;
- Infrastructure: accessible bus stops, path to stops, curb design;
- Standards: D409 revisions.

Fig. 2 Example of rear facing position used by OC Transpo in Ottawa

2.2 Experience with securements in the US

2.2.1 Legislation

The Americans with Disabilities Act (ADA) in the US requires two locations for mobility aids, a securement device for the mobility aid and an occupant restraint, for vehicles over 22' length. The objective of the securement and the occupant system is to protect the wheelchair occupant and the wheelchair.

Securement devices are specified as:
"Securement systems on vehicles with GVW of 30,000 lb. or above, and their attachments to such vehicles, shall restrain a force in the forward longitudinal direction of up to 2,000 lb. per securement leg or clamp mechanism with a minimum of 4000 lb. for each mobility aid.. For vehicles with less than 30,000 lb. of GVW the restraining force per securement leg or mechanism shall be 2500 lb. with a minimum of 5000 lb. per mobility aid.

2.2.2 Legal requirements versus utilisation of requirements

To verify how legal requirements and the application of these requirements are carried out, the Architectural and Transportation Barrier Compliance Board (ATCB), and the FTA were contacted. The following provides a summary of their comments.

ADA legislation is in effect since 1991. This requires that transit systems with older buses built and in service before 1991 and equipped with any kind of securement system can continue using these systems until these buses are replaced, as long as they can accommodate common types of wheelchairs with an envelope of 30" wide, 30" high, and 48" long. Only buses manufactured after 1991 must comply with ADA legislation and provide a securement system as stated above, and an occupant three point belt system with shoulder harness. The use of the wheelchair securement is mandatory, the use of the occupant restraint system is not.

The rationale for the application is that the wheelchair be secured to the bus the same way as a regular bus seat, but the use of the occupant system should not be mandated since the wheelchair passenger would be the only passenger in the bus wearing belts. If the wheelchair passenger wishes to use the occupant belt system, he/she can certainly do so.

An amendment to ADA now also indicates that the wheelchair passenger must be secured in the forward facing position only.

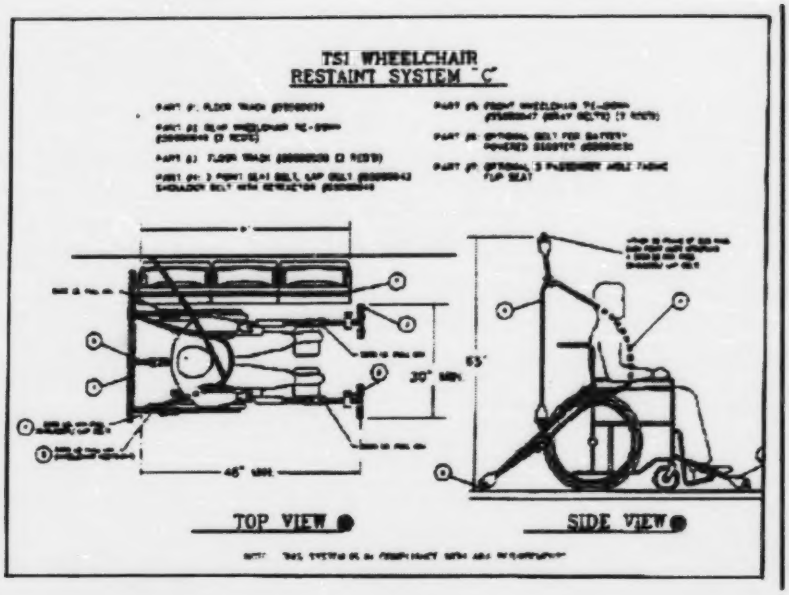

Fig. 3 Example of ADA compliant wheelchair securement and passenger restraint system

2.3 Experiences in practice

ADA legislation requires that all transit buses built after 1991 must be equipped with a wheelchair securement and occupant restraint systems, if they want to take advantage of the funding provided by the Federal government. In an APTA survey conducted in 1993, the results of use of securement system in transit buses indicated that the operator must secure the wheelchair and the occupant restraint. At this time it was not clear, if the deployment was actually enforced. Follow-up interviews carried out now indicate that there are two scenarios, one for new buses that must comply with the ADA for securement and occupant systems, and the other is for large fleets of older buses that, although having some form of securement, do not have to comply with ADA.

Nevertheless, several questions remain regarding the practice, which were posed recently to a number of transit systems in the US and which revealed the present practices:

<u>Before 1991</u>

Buses equipped with older securement systems, e.g. wheel rim lock, two-belt systems, 4 belts systems and others, must accommodate commonly used wheelchair types, but must not have occupant systems. Because of liability, most states have made the use mandatory, although others have not. The operator or a companion/assistant of the wheelchair passenger may deploy the system ,but the operator is responsible for its use. The operators are trained to use the system. It is assumed that because of the longevity of the older bus fleets, complete replacement will take place around the year 2010.

After 1991

All newly purchased buses must be equipped with a securement system and an occupant restraint system according to ADA. The system prevailing in use is the Q-straint or equivalent, consisting typically of 2 rear belts, (either retractable and fastened to the seat/floor, or portable and stowed in a box), and 2 front belts , (retractable or portable to floor). The occupant system consists of a lap and shoulder harness.

For systems used in new buses the operator is trained, must deploy and is responsible for the securement. This responsibility is specified in the operator's contract with the transit system. Securement is however not systematically enforced: some transit systems spot check if operators comply with their responsibility; others do not. Although operators are trained for applying the systems and are also receiving sensitivity training, there is nevertheless the inconvenience voiced by operators for the use of belts , e.g. getting on knees, reaching under the chair, and coming in physical contact with the passenger. Similarly, wheelchair passengers frequently voice their discomfort with the securement process, and some view it as degrading.

The wheelchair passenger can refuse the use of seat belts, but cannot refuse the deployment of the securement system. If he/she does, the operator is instructed to refuse transportation and deboard him/her. In practice this does not happen. The operator may explain that this safety measure is in the best interest of the passenger, or have a patron sign a waiver. In practice most operators take the path of least resistance.

Recent discussion sessions at APTA conferences have indicated that this problem is becoming more serious. Wheelchair users are reportedly challenging operators and transit systems over the requirement to be secured at all, as per a "rights" issue. Whatever the reason, if securement is not being systematically enforced, the theoretical level of safety offered by forward facing systems is severely compromised, diminishing its main advantage over rear facing systems.

3. EXPERIENCE WITH REAR FACING POSITION DESIGN IN EUROPE

3.1 European background

Low-floor buses in Europe were introduced in the late 1980's with the objective of making access and egress for all passengers easier, faster and safer. Originally, only the areas near the service doors had a low floor, the rest of the bus could only be accessed over steps or ramped floors. In the meantime "low floor throughout" has become the norm. In order to avoid seat loss, several seats are positioned - some rear facing - over the wheel wells but require one or two steps to get in or out of. The idea of making these buses accessible to persons using wheelchairs, persons with strollers, large baggage etc. seemed to be a natural extension. In Germany, the UK and France the development of rear facing positions had began based on successful tests of unsecured wheelchairs on platforms. Rear facing positions were designed and implemented in low floor buses to increase access to transit buses with a high degree of independence for the user of the wheelchair and to decrease involvement of the operator for this group of passengers. By the end of the 90's, most European countries including East European had adopted the rear facing position on low floor transit buses as a safe mode for travellers in wheelchairs. In the UK, in 1995 as part of the Disability Discrimination Act, the government proposed guidelines and specifications of accessibility features for buses and coaches of different sizes.

Historically, the use of a designated "compartment" in Europe goes back to the 1930's. For instance, the subway system (S and U- Bahn) in Berlin, Germany introduced a "Mother and Child" section on each train consisting of a large space with a central open area and seats along the walls facing the centre. This allowed accommodation for several mothers with their strollers or when travelling with young children and luggage. There were vertical stanchions in the centre of the area, as well as near the seats for the traveller to hold onto. This design is still in use today.

It should also be noted that rear facing seats have traditionally been used in the design of urban buses, trams, subway systems, and intercity trains in Europe. The notion of rear facing has therefore not been an issue in Europe.

3.2 Wheelchair passenger profile

In Europe a large number of standees are allowed in a bus travelling up to 60 km/h, because of the high volume of passengers and short distances between stops (1-3 minutes). There are no official data on the amount of wheelchair passengers using low floor buses, but it is estimated to be in the 0.02% range of total bus ridership. In Europe the rider profile for wheelchair passengers is different from the North American. According to the transit systems investigated, the majority of riders in wheelchairs use manual and sports chairs; very few persons with electric wheelchairs or scooters use urban buses. Possible explanations are that distances travelled in cities are shorter, the climate is not as extreme as in Canada or northern USA and an electric power chair can actually travel on sidewalks to cover short distances to shopping etc. If a person in a wheelchair or scooter chooses not to use the public bus, the paratransit system is available. The choice is made by the wheelchair passengers according to their abilities. He/she decides which mode of transportation is the most convenient.

3.3 Description of rear facing position

The rationale for the introduction of the rear facing position with its back and headrest was to provide:

- a person in a wheelchair with the same level of safety as all other seated passengers, for regular operation of a transit bus, including severe braking and cornering,
- this person with the same degree of independence as all other bus passengers, and
- other passengers with large equipment, such as strollers, with a place to accommodate their requirements.

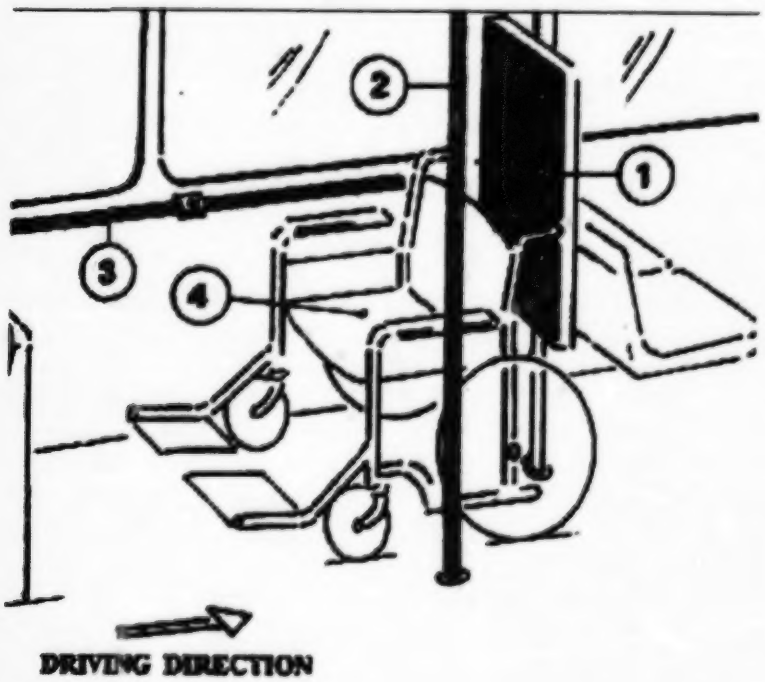

Fig. 4 Rear facing position schematic: 1) back and head support panel; 2) aisle stanchion; 3) horizontal handrail with stop request button; 4) rear facing wheelchair

As shown in Fig. 4, the rear facing position is an open rectangular floor area with one long side along one window wall, and with the other long open side facing the aisle. The short side facing the front of the bus contains a fixed load-bearing device, consisting of an upholstered panel extending from about seat height to head height (for a passenger in a wheelchair) and a steel structure connected to the floor, side walls and/or ceiling. The panel is sometimes slightly inclined or just vertical and is wide enough to cover the back and head of the wheelchair passenger, but narrow enough to clear the wheelchair's handlebars. Its function is to absorb deceleration forces over a large area.

To prevent the wheelchair from moving into the aisle during severe cornering a vertical stanchion on the aisle side (London Transport), or a retractable lap belt on the bus wall (Berlin), are used. Some transit systems (e.g. Aachen) have not felt this to be necessary.

In Europe, the rear facing position is usually located opposite the centre door, or when two spaces are made available, opposite each other near the centre door. Boarding /alighting in Europe is mostly through the centre door, although the UK operated single door accessible buses with access through the front.

3.4 Use of rear facing position

The boarding request is initiated by a person in a wheelchair waiting at the bus stop by pressing a call button on the outside of the bus near the centre door, or by hand signal to the operator. The call button request illuminates an indicator light at the operator's station. The operator visually verifies through a mirror or video camera, if the boarding area on the platform is clear for the ramp to slide out before deploying the ramp.

The ramp can only be deployed when the centre door is closed. This is a safety measure which is designed to prevent any passenger from stepping onto the moving ramp while exiting or boarding. The person in a wheelchair can board the ramp facing either frontwards or rearwards, depending on which he/she feels is a more convenient mode. Persons using scooters often choose to board rearward, because it reduces manoeuvring the scooter inside the bus.

Once the person in a wheelchair boards up the ramp at the centre door, he/she turns inside the bus. The wheelchair passenger must manoeuvre into the location and position him/herself facing to the rear, with the back and head resting against the panel. Only in this position can deceleration forces be absorbed adequately. No assistance from the operator or other persons is required to complete the boarding and alighting procedure. There is no need to apply belts, hooks or other equipment, except where lap belts are used instead of aisle stanchions. A sign in the location indicates that the wheelchair should be positioned in the rear facing position. The wheelchair passenger is required to apply the brakes to help prevent sliding of the wheelchair/scooter when cornering or going up steep hills. Manoeuvring in and out of the position is done without operator involvement. A horizontal handrail on the bus wall is provided for passengers in wheelchairs to hold onto. If no stanchion is provided, a retractable belt on the bus wall is to be attached to the wheelchair, which must be operated without the help of the operator.

The rear facing position location is not only used by passengers using a wheelchair, but by persons with a baby stroller, persons with large luggage, or by standing passengers. Some operators even allow passengers with a bike in this area It is this multi-purpose use of the position which has made it a success in Europe. Some systems provide flip up seats in this area, others do not. For the wheelchair passenger, manoeuvring into the position is easier if the position has no seats, because it makes vacating the area easier for people who are standing.

3.5 Legislation

The transportation of wheelchairs facing to the rear against a load bearing panel has been accepted by many European countries as a safe mode of transportation by their Transport Ministries.

3.6 Manufacturers

There are currently several manufacturers of low floor buses, including: Mercedes Benz, MAN, Volvo, Scania, Van Hool, Denis, Fiat, Herlioz etc. Within the spirit of the European Union the tendency goes towards standardising low floor buses in size, performance and equipment, and to provide consistency for all users. It is expected that within the next few years one common bus type will evolve with the same standards applied in all countries of the European Union.

3.7 Accident rates

The Aachen Transit System in Germany has now been operating for over ten years low-floor buses (standard and articulated) equipped with a rear facing position for wheelchairs. There has only been one accident reported which involved a mother with a stroller: a baby was carried in a high-level stroller with several shopping bags, creating a very high centre of gravity. It was left unattended in the location and tipped over when the bus made a sharp turn. Fortunately, no one was injured, but it prompted the transit system to investigate if a vertical stanchion at the aisle side should be added to the compartment. The rear facing position system in Aachen has no aisle facing vertical stanchion. The transit system does not keep track of the number of wheelchairs, strollers, or people using large baggage, transporting bikes etc. using the system, but they estimate that approximately 1 person in a wheelchair per 10,000 passengers uses the system. In London, where operation of low floor buses has been introduced for several years now, no accidents have been reported either.

3.8 Priority seating

In London, the wheelchair position is equipped with three flip-up seats along the bus wall. These seats are always in the up position so that the person in a wheelchair is not required to push them up first. This area is not dedicated as priority seats for elderly persons or other passengers with mobility aids, e.g. persons using crutches, canes or walkers. The reason is to avoid the conflict which can arise when these seats would be occupied by such a person and a wheelchair passenger would board. Therefore, two experiments are underway in London. One is to dedicate regular seats near the operator as priority seats in order to provide better communication between the passenger and the operator. The problem with this approach is that the seats right behind the operator must be accessed using two steps, because they are located over the wheel well. This of course creates problem for persons with difficulties negotiating steps, especially for many seniors.

The other approach is to provide a second open compartment opposite the rear facing position, near the centre door, equipping it with front and rear facing flip up seats and designate them as priority seats. A rear facing seat would also provide the safest position for an elderly person or child in case of severe deceleration. In case of a club seating arrangement the forward facing seats must be equipped with grab rails and slip resistant seat cushions.

In the Aachen and Berlin transit systems, there are no seats in the rear facing position. This provides more standing room in case the area is not occupied by a wheelchair user or other passengers, e.g. mothers with strollers, requiring the space. In both cities there is only one rear facing position per bus.

3.9 COST 322 program

The European CO-operation for Science and Techniques - COST - is a program which was established in 1971 to co-ordinate fundamental, pre-normative, pre-competitive research or activities financed at national levels in the 25 European member countries. The COST 322 Action started work in 1993 and involved ten participants. Its objectives are to place emphasis on the needs of public transport in order to reduce the use of personal cars, to provide accessible, efficient and reliable service for the population as a whole, and to reduce the impact of traffic congestion and pollution.

Under this program, tests were carried out by a group of researchers in France with the participation of the Lyon Transit System. An experimental set-up was designed with the aim of identifying transport situations dangerous for a wheelchair user, and to demonstrate safety solutions having the minimum amount of constraints for the passenger.

The test scenario included the use of manual and electric wheelchairs, a 50th percentile dummy (75 kg, 1,75 m), set-up in a low-floor bus, type Van Hool A500.
The following forces were reproduced as a typical example of conditions which transit buses would experience;

- sharp acceleration up to 0.4 g
- sharp deceleration from 0.4 g to 1.0 g
- transversal acceleration (violent change of direction)

Several wheelchair positions were selected:

- facing front
- facing sideways
- facing 45 degrees to the rear
- facing to the rear

A number of different securement systems were used:

- none
- Quick-lock (4 belts)
- bulkhead
- back & headrest (load-bearing device)
- back & headrest with aisle support (armrest)

The following table shows the test results

Table 1 Test Results - COST 322

		Results under following conditions		
Securement type	**Facing**	**Braking**	**Acceleration**	**Cornering**
No securement, brakes only	front	bad	satisfactory	bad
4 belt system	front	good, if belts used	good	good
Sideways, with brakes,		satisfactory	satisfactory	bad
Sideways with front wall and belt		good	satisfactory	satisfactory
Sideways with rear wall and belt		bad	good	bad
45 degree to rear	rear	satisfactory	satisfactory	bad
Vertical panel/ bulkhead	rear	satisfactory	good	bad
Back and head rest	rear	good	good	bad
Back, head rest & aisle support	rear	good	good	good

good - wheelchair stays upright under sharp acceleration, braking, and cornering
satisfactory - wheelchair begins rocking, stress on dummy
bad - wheelchair is tipping, dummy is falling

The results from the COST 322 project reconfirmed findings from the previous research by the German Ministry of Transportation, conducted in 1991-1992, which was summarised in CUTA's STRP Report 10 (Urban transit Bus Accessibility Considerations, Appendix C). Together this body of research illustrates the acceptable level of safety offered by the rear facing position design under normal bus operating conditions, and has lead to widespread adoption of this approach across Europe.

3.10 Findings from European Experience

The European research and experience has clearly shown that a rear facing wheelchair passenger in a rear facing position can afford the same or higher degree of safety as that offered to regular seated passengers, and enjoy at the same time complete independence when travelling on a transit bus. The following section documents experience in the UK, France and Germany based on telephone interviews with transit operators and experts in these countries.

United Kingdom

In the Disability Discrimination Act of 1995, the government proposed vehicle accessibility regulations for the public service. They include proposed specifications for wheelchair access, access features for large buses, small buses and coaches (Disability Discrimination Act 1995, The Government's Proposals for Buses and Coaches, December 1997).

Equipment

In the United Kingdom, two wheelchair positions are used on standard 12 m (40') buses with fixed aisle stanchions. Boarding and alighting is over a sliding ramp at the centre door. The operator observes the process via a video monitor or inside mirrors at his station and through outside mirrors. Some wheelchair positions have three flip seats along the bus wall which are always in the up position. Buses are equipped with other rear facing seats. Some operators equip buses with a second compartment without a back panel and not to be used for passengers in wheelchairs, but with a flip seat to accommodate persons with strollers.

Operation and feedback

Experience has shown that the location of the aisle stanchions - when positioned too far into the aisle - can create problems for other passengers when moving through the aisle. This can be the result of the flip up seats design forcing the lateral dimension of the stanchion into the aisle. For this reason experiments are underway to design the lower part of the back panel as a flip up seat and remove the wall mounted flip seats. In addition, if the longitudinal distance of the stanchion from the back panel is not correct it does not prevent the wheelchair from moving into the aisle.
The compartment is also used by many other persons, e.g. mothers with stroller, persons carrying large baggage etc.

An extensive survey was carried out by the Transport Research Laboratory from 1994 until 1998 in London and North Tyneside for the use of low floor buses. All buses were equipped with a rear facing position, a back panel and a handrail. The results identified a few issues of concern: buses unable to position parallel to the curb because of parked cars, ending up with a large gap that makes it difficult or impossible for passengers in wheelchairs to board; damage of front tires from approaching curb at an angle etc. The demonstration identified considerable benefits for all passengers from the low floor bus. For passengers with strollers, the low floor presents a significant benefit, as well as for ambulant disabled passengers who needed to use the handrails less. For passengers in wheelchairs, it increased their opportunity to use public transit as well as their mobility and independence.

Fig. 5 Rear facing position with aisle stanchion, and compartment for strollers on opposite side used in London low floor buses

France

The rear facing position is mandatory in France for urban bus routes only. Outside the urban areas, the wheelchair passenger must travel in a forward position with the wheelchair properly secured to withstand severe braking.

Equipment

Urban buses are equipped with one or two positions for wheelchairs. The wheelchair position is mostly placed at roadside, near the centre door, even in those buses that board passengers in wheelchairs via the front door. Usually passengers in wheelchairs board and exit via a sliding ramp at the centre door. There are no flip seats in the designated wheelchair compartment. Typically fixed aisle stanchions are used, but manufacturers in France are also experimenting with a movable arm connected to the back panel to prevent the wheelchair from moving into the aisle. The movable armrest has the advantage of requiring less manoeuvring space for the wheelchair passenger to back against the back/head rest. The down side of this approach may be the fact that for many wheelchair users it may be difficult to reach back and operate the arm rest. Misuse could also be a problem, e.g. other passengers sitting on the arm, or the arm being in the way of other passengers when not in the up position. There is a separate call button in the wheelchair position to alert the operator. Some bus operators are providing a visual "next stop" display, but mostly an audio announcement is used. Typically buses have also rear facing seats over the wheel wells.

Fig. 6 Rear facing position with movable armrest (shown in up position) instead of stanchion; no flip-up seats in wheelchair compartment

Operation and feedback

In 2000, nearly 100% of urban buses (standard 12 m or articulated) in France are low floor, but less than 50% are outfitted with a wheelchair compartment. For suburban use many low floor buses have now only two service doors in order to increase the number of seats, as compared to three for urban service. In a survey carried out in the City of Grenoble, no adverse reaction to the rear facing position was noted from passengers in wheelchairs, although objection was found for having only one wheelchair position on standard (12 m) buses. Articulated buses are equipped with two wheelchair positions. There is no evidence of any accidents in France to date resulting from the rear facing position design, but ridership is still very low. One of the reason for low wheelchair passenger ridership may be related to the fact that many bus stops are not accessible for passengers using wheelchairs, thus the transit systems cannot actively promote accessibility. Accessible buses in Grenoble and Strasbourg are more frequently used with a mean ridership of 20 - 40 persons in wheelchairs travelling per week.

Germany

Equipment

Germany is probably the country that has the largest number of accessible low floor buses in service. A visit in 1997 revealed that even the former East German transit operations are now equipping their fleets with accessible low floor buses and low floor trams. Large cities like Berlin and Hamburg are also using accessible low floor double-decker buses. All low floor buses and trams have at least one wheelchair position. Buses have sliding ramps at the front or centre door for boarding and alighting. The rear facing

position in standard low floor buses is typically positioned opposite the centre door with a sliding ramp at the centre door that is operated by the operator. The position has no flip seats, and no aisle facing stanchions. There is a retractable belt mounted to the bus wall that can be used by a user in a wheelchair to hook onto his/her chair, thus preventing it from moving into the aisle. The operation of the belt is the user's responsibility. On standard 12 m low floor buses the back/head rest panel is positioned at the end of the compartment facing the rear of the bus. A horizontal hand rail along the bus wall is designed for users of this position to hold onto. A separate stop request button alerts the operator if the occupant of this position wants to exit. It is not the operator's responsibility to ensure that passengers in wheelchairs position themselves facing rear. Although a sign and symbol in the compartment indicate that wheelchairs should be positioned facing to the rear, some passengers will also face forward. This has led some transit operations to eliminate the back panel completely and equip both ends of the compartment with a padded horizontal bar at back height

City trains, trams and subways such as the S-Bahn (surface city train) and U-Bahn (underground subway) in Berlin provide one large compartment in one car for passengers in wheelchairs, mothers with strollers, persons carrying bicycles or persons with large baggage. The compartment in trams and subways has no fixed back/headrest panel. Lateral handrails on seat backs and at the ends of the compartment are padded, the passenger in a wheelchair can ride in any position, facing front or rear. Station platforms and stops for trams are at the same height as the vehicle's floor with a horizontal gap of approximately 30 mm, thus not requiring any ramps.
Trams and some buses have an electronic text displays combined with an audio message to indicate the name of the next stop. These displays are mounted at the ceiling and are visible from both sides reaching all passengers facing forward or rear.

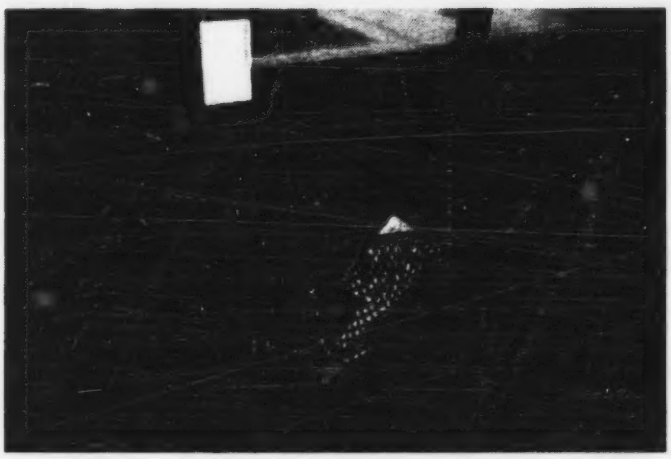

Fig. 7 Position for wheelchair and stroller without back panel, seats or stanchion in double-decker low floor bus in Berlin, Germany. Retractable lateral belt is mounted on window wall.

Operation and feedback

In Germany the compartment is not only used by passengers with a wheelchair, but more so by mothers with strollers, and passengers with large luggage. Some operators allow even bicycles to be transported in the compartment. An update in May 2000 revealed that many transit systems, especially private enterprises, have eliminated the back panel altogether. In case of severe braking, the passenger is held by a padded transverse tubular support at lower back height. Each compartment has a horizontal handrail along the bus wall for the passenger to hold onto, some transit systems provide a wall-mounted retractable belt. For those systems using a back panel, manufacturers such as Mercedes offer smaller (lower) back supports combined as a flip-seat. Some passengers in wheelchairs prefer to travel facing forward and position themselves accordingly, without objections from operators. As far as accidents are concerned there is no central institution in Germany that collects relevant data. Some transit systems indicated that there were several cases where passengers in wheelchairs rolled or tipped into the aisle but without resulting in injuries, probably due to the fact, that they did not or could not hold onto the handrail, or did not use the retractable belt. Like in other countries, public transit systems face enormous funding problems in Germany, therefore some systems, e.g. in Bremen, have eliminated the kneeling function, saving about $120,000 CDN per year in fuel cost. In Berlin, some buses were equipped with a ramp lift at the front door. These are now replaced with less costly electric ramps at the centre door. Other operators have eliminated the sliding ramp and are using the flip ramp for the same reason.

4. CANADIAN EXPERIENCE WITH REAR FACING POSITION DESIGN

In Canada, many transit operators use a forward facing position, modified from that required in the United States, involving a smaller number of belts, and not necessarily compliant with ADA. However, transit operators in Hamilton, Grand River (Kitchener & Cambridge) , Victoria, Ottawa, and Montreal are presently implementing rear facing positions, located either at the front or near the centre door. Front or centre doors are being used for entry and exit. Flip ramps or sliding ramps are in use for boarding/alighting, and visual and audio displays are investigated to inform rear facing passengers of the next stop.

In Canada, two positions for wheelchairs are provided for large low floor transit buses, except for the case of Montreal, which presently offers only one position. The following summarises experiences of several transit systems.

4.1 Hamilton

The Hamilton Street Railway (HSR) company was the first transit system in Canada to introduce rear facing wheelchair positions on a low floor bus in regular operations. HSR introduced in 1996 the Accessible Low Floor (ALF) service, on modified New Flyer buses with two rear facing positions on several routes in Hamilton. The bus was equipped with a flip ramp at the centre door that was operated by the operator who had to get up from his seat and go to the door. The two wheelchair positions were located opposite each other: one on the curb side and one on the roadside behind the front wheel wells.

In 2000, HSR is using a total of 80 low floor buses, comprised of Nova, New Flyer and Orion models, with rear facing wheelchair positions.

Equipment description

There are two rear facing wheelchair positions per bus located on opposite sides. Each position has an aisle stanchion and a lap belt. Depending on the bus model there are between two and four flip seats in the wheelchair compartment in the down position when not in use. Each compartment has a separate stop request. Most wheelchair types, from manual to power, three wheel and four wheel scooters can be transported. The centre door is used as the entrance and exit for persons using a wheelchair. The Nova Bus models have a sliding ramp, New Flyer and Orion models a flip ramp. Nova Buses have 4 regular seats that are also rear facing.

Operation

During 28 days between May and June 2000, an average of 52 passengers with wheelchairs were transported per day. The operators responsibilities include kneeling, ramp deployment, fare collection, vacating seats in wheelchair compartment and ensuring that passengers in wheelchairs position themselves facing the rear. Each operator receives two to four hours of awareness instructions and training. For ech new bus model they receive an additional 20 - 30 minutes refresher course. If passengers in wheelchairs are unable to board/exit, or if their wheelchair type/size cannot be accommodated, he/she will be referred to the paratransit service. Average boarding time per wheelchair passenger is between 2 and 3 minutes. Courtesy seats for seniors are not located in the wheelchair

compartment but behind the front wheel well, curb side. The rear facing position has been accepted by passengers using wheelchairs. No accidents have been reported, only infrequent minor sliding of wheelchairs. Other problems reported are that not all bus stops are accessible and that some passengers are uncooperative with vacating seats in the wheelchair position area.

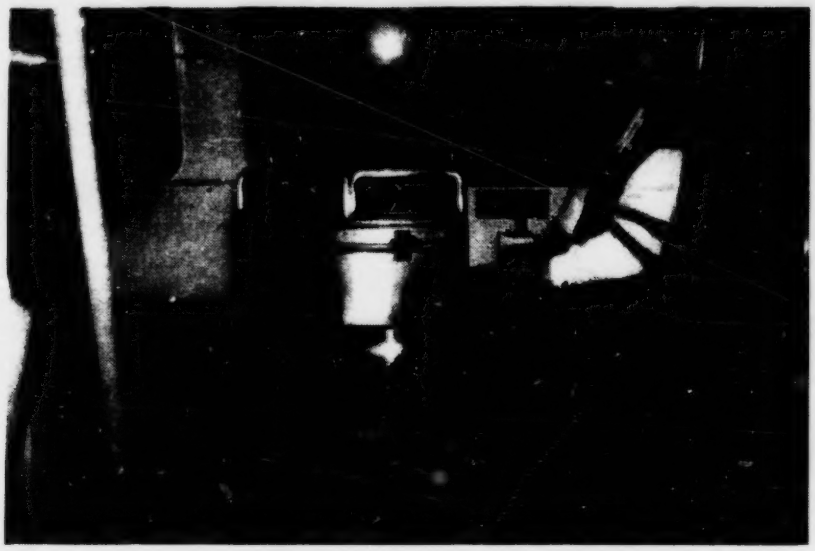

Fig. 8 Rear facing position with aisle stanchion and flip up bench in Hamilton's low floor bus

Focus Group

In November 1997, HSR was the only transit system in Canada using the rear facing position. A focus group meeting was held in Hamilton and attended by the researcher. Seven persons with different disabilities and types of wheelchairs provided their comments. In addition, 18 persons who used the Accessible Low Floor Bus (ALF) service were interviewed by phone for their experience. The following is a summary of their experience. Most persons had used the service several times during one year, ranging from about 6 times per year to several times each day.

Ramp

Persons using manual, sports and electric chairs used the ramp front first when boarding; many persons using scooters preferred to back in over the ramp. This allowed them to back right into the wheelchair position without any additional manoeuvring. They noted that the side guards of the ramp should be higher to prevent the scooters from slipping off. It was also indicated that when the ramp swings onto the side walk, passing persons on the sidewalk sometimes do not notice or hear the audio alert signal and walk into the ramp.

The ramp sometimes experienced mechanical problems, thus leaving wheelchair passengers stranded and having to wait for the next bus.

Manoeuvring into rear facing position

Turning and backing into the rear facing positions was not a problem during non-peak hours. During peak hours standees must move to clear the path for the wheelchair, and passengers seated in the wheelchair locations have to be asked to vacate their seats. Both problems present difficulties: standees do not know where to move because they do not know in which direction the wheelchair is proceeding; and passengers occupying seats located in the wheelchair compartment do not know or do not want to know that they must vacate their seats.

Wheelchair location

There was no clear preference for using the curb side or road side location. Very few passengers in wheelchairs used the wall mounted retractable belt that is there to prevent the wheelchair from moving/tipping into the aisle. They felt safe without using it.

Perception of safety

All persons felt safe in the rear facing position. None reported motion sickness. Some would prefer to face forward but only if it means the same degree of independence as provided by the rear facing position.

Some persons do not like to be the only ones facing rear and being "stared at" by other passengers, others had no objections at all.

Stop request control

None of the interviewed had difficulty seeing or operating the stop request button, but some scooter users found the location of the button inconvenient, because it is behind their armrest.

Next stop location identification

This was mentioned to be inconvenient by those persons who do not know the route and rely on the information from the operator to identify the next stop. The operator's information is not always consistent, e.g. forgets to announce stop, or does not speak clearly.

Rear facing

All passengers preferred the independence of the rear facing system, not having to rely on other persons for help, despite the inconvenience of facing rear and being stared at, and not being able to see upcoming stops.

Operator attitudes

The lack of awareness and training of operators was mentioned at the time as the greatest issue by all passengers. Comments included: rough and jerky driving when wheelchair passengers are on board; forgetting to operate the ramp despite receiving the stop request signal; not knowing how to operate the ramp; and not assisting in vacating seats in the wheelchair position. Operators did not always insist that wheelchair passengers must position themselves facing to the rear.

Fare payment

HSR has a voluntary fare payment system for persons using wheelchairs. In the eyes of the public this creates the impression that they are getting a "free ride".

General public

Children play with wheelchair stop requests. Some passengers seated in wheelchair location are ignorant and do not vacate seats. Public is unfamiliar with wheelchairs, their turning radii and user's movements, intended paths etc.

4.2 Grand River Transit (Kitchener & Cambridge)

In June 2000, Grand River Transit was operating seventy 12 m (40 feet) low floor buses, 62 were New Flyer, 4 Orion, and 4 Nova models.

Equipment

62 New Flyer models are equipped with one front and one rear facing wheelchair position. The rear facing position is at curb side. 4 Orion and 4 Nova models are equipped with 2 wheelchair forward facing positions in tandem configuration. The rear facing positions are equipped with a fixed back panel. 14 buses use the aisle stanchion, 48 buses have a wall mounted lateral belt to prevent wheelchairs from moving into the aisle or tipping. All bus models use the front door for boarding and alighting and are equipped with a flip ramp. A courtesy seat is assigned in all bus models at the front of the bus, not in the location for wheelchairs. In each wheelchair position are either two or three flip seats that are in the up position when not in use.

Operation

Grand River Transit transports about 30 passengers in wheelchairs per week. The operator's responsibility includes: kneeling, ramp deployment, fare collection and ensuring that passengers vacate seats in wheelchair positions if required. He/she is not responsible for assistance in securing the wheelchair even for a forward facing position, or ensuring that passengers face to the rear in the rear facing positions. The average boarding time per wheelchair passenger is about 1 minute. No complaints have been received to date from passengers using the rear facing position. Each operator receives about 8 hours of awareness and accessibility training, but no refresher courses. If a passenger in a wheelchair/scooter is not able to board the bus on his/her own or the wheelchair/scooter cannot be accommodated in the bus, e.g. because of size, turning radius, etc., the passenger will be referred to the specialised paratransit operation.

4.3 Ottawa

As of May 2000, OC Transpo in Ottawa was operating 20 NOVA 12m (40') low floor buses and 140 Orion VI 12m (40') low floor buses, all equipped with two rear facing wheelchair positions. On order for the end of 2000 and 2001 are 67 articulated New Flyer low floor buses which will also be equipped with two rear facing wheelchair positions in the front section.

Equipment description

All NOVA buses are equipped with two staggered wheelchair positions located opposite each other behind the front wheel wells. An aisle stanchion is used to prevent movement into the aisle. Each wheelchair compartment is equipped with a three seat lateral flip-up bench that is in the down position when not used by a person in a wheelchair. A separate stop request button is located at each compartment and provides the operator with a separate light and chime display. Boarding and alighting is via a sliding ramp at the front door. Most common types of wheelchairs and scooters can be accommodated in the locations. The NOVA has four other rear facing regular seats at the rear, but they are not very popular for the general public, except for students. Presently there is no separate visual "Next stop" announcement for rear facing passengers, except for the operator's general audio announcement

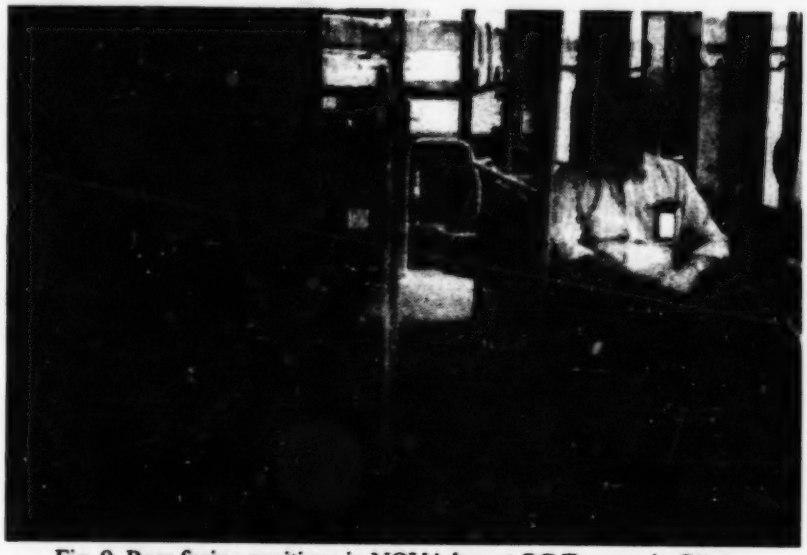

Fig. 9 Rear facing positions in NOVA bus at OC Transpo in Ottawa

Orion VI 12 m (40') low floor buses are equipped with tandem wheelchair positions located at road side. A fixed aisle stanchion is used to prevent moving of the wheelchair into the aisle. To provide adequate manoeuvring room for wheelchairs, there is one row of side-facing seats opposite the tandem wheelchair positions. In each compartment is a side-facing three seat flip bench with seats in the down position when the compartment is not used by a person in a wheelchair. A separate stop request button is located at each compartment and provides the operator with a separate light and chime display. Boarding and alighting is via a flip ramp at the front door. Most common types of wheelchairs and scooters can be accommodated in the locations. Orion VI buses have a rear door behind the rear axle with steps leading into the passenger room. There are no rear facing seats for the general public. Presently there is no separate visual "Next stop" announcement for rear facing passengers, except for the operator's general audio announcement

Fig. 10 Orion VI low floor bus with rear facing wheelchair positions in tandem at OC Transpo in Ottawa

New Flyer articulated buses have been ordered by OC Transpo and two rear facing wheelchair positions in tandem are planned in the front section of the bus. Boarding and alighting will be through the front door via a flip ramp.

Operation and feed-back

For all bus types, an attendant for the person using a wheelchair can travel free providing that he/she takes care of the accommodation, manoeuvring and boarding/alighting of the person in the wheelchair, should this person be unable to do so. If a person in a wheelchair cannot be accommodated, e.g. because of the size of the wheelchair or the user's inability to board/alight by him/herself, that person can use OC Transpo's paratransit service. Fare payment for all passengers is at the front of the bus to the operator using cash exchange or a pass. Fares are the same for all passengers, including those using mobility aids. The position of the aisle stanchion has proven to work for manual, electric and power chairs, but scooters can still tip if their users are not holding onto the stanchion. Most passengers using wheelchairs/scooters were found to use off-peak travel times to avoid crowding at stops and within the bus. Average boarding times for passengers using wheelchairs/scooters are about 20 seconds. Presently courtesy seats are in the same location as the places for wheelchairs, which can create a conflict. Those passengers who cannot travel facing rearwards are referred to ParaTranspo, OC Transpo's paratransit service. So far very few passengers have been reported who cannot travel in this position. All operators at OC Transpo are provided with a four hour hands-on practice and awareness training to transport passengers who are disabled. They are also provided with regular refresher courses.

The responsibility of the operator includes kneeling the bus, deployment of the ramp, fare collection, vacating the seats in the wheelchair compartment for the passenger in a wheelchair if required, and

verifying that the passenger in the wheelchair is located in the compartment. The operator is not responsible for ensuring that the passenger in the wheelchair faces to the rear.

Prior to final vehicle design trials were carried out in a stationary NOVA bus with scooters and electric powered wheelchairs to verify if the staggered opposite rear facing configuration and dimensions allowed for convenient entrance, transport and alighting. In addition, tests were carried out replacing fixed aisle stanchions with movable armrest mock-ups.

The results of the trials indicated that:

1. The lay-out provided convenient access for the test subjects and their mobility aids, and that the lay-out could be further improved with some minor modifications.
2. Persons using a wheelchair or scooter preferred the fixed stanchion over the armrest concept, mainly due to the difficulties in its manual operation (reaching, pulling down, judging lateral wheelchair clearance, etc.) A power assisted operation may provide better results. The movable armrest definitely provided more space to get in and out of the position and turn into the aisle.
3. Boarding and alighting times - without the presence of other passengers - varied from 25 seconds each way for electric wheelchairs, to over one minute for some scooters. It was found that these times depend much on the skills and abilities of a scooter operator and his/her familiarity with the interior of the bus. Persons with limited driving skills, an inability to turn their head or upper body, and unfamiliarity of the bus interior required more time.
4. Recommendations included that trials be carried out with subjects in an operating environment under service conditions.

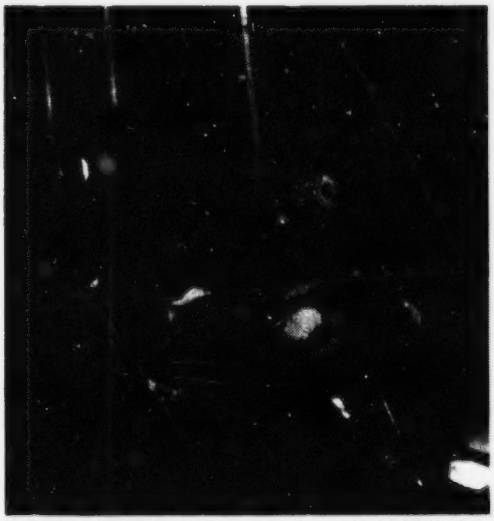

Fig. 11 Rear facing position with movable armrest mock-up in NOVA bus at OC Transpo, Ottawa

4.4 BC Transit, Victoria

In May 2000, BC Transit in Victoria was operating all its 12 m (40') New Flyer low floor buses with two forward facing wheelchair positions. The securement consists of two rear straps and an angled backstop for manual, power wheelchairs and scooters. Scooters require an additional strap

to be applied over the front platform. The use of an occupant belt is optional.

New Equipment
BC Transit in Victoria has now 51 Dennis Dart SLF 9.3 m (30') in service, 46 Dennis Dart SLF 10.5 m (35') on order, as well as 10 Trident 12m (40') low floor double-decker buses.

Recently Victoria received 51 new Dennis Dart SLF 9.3 m (30'). 5 of these buses have two service doors and are equipped with one rear facing wheelchair position at curb side. 46 buses have one service door and are equipped with two wheelchair positions in tandem at curb side.
Boarding and alighting for both bus types is through the front door via a sliding ramp. The ramp slope is 1:4 when deployed to the road, less to the curb. Each rear facing wheelchair position is equipped with a load bearing back panel and two retractable belts, one located behind the back panel at waist height aisle side, the other diagonally at the bus wall lower left corner of the compartment. If required, either can be used individually to prevent the wheelchair/scooter from moving into the aisle or both can be hooked together to form a harness. The load bearing panel converts into a flip-up rear facing seat when the compartment is not occupied by a wheelchair. There are no other flip seats in the compartment area. Each compartment has a separate stop request button. For rear facing passengers there is no other announcement available for next stop, except for the general audio message from the operator.

For the ordered double-decker buses, a combination securement system for wheelchairs is planned, which will allow the passenger in the wheelchair a choice, either facing forward with the use of belts, or facing to the rear without the use of belts. This combination requires a longer compartment of approximately 1.98 m (78"). Each double-decker will have one securement position located at road side behind the operator.

Operation and feed back
At this time there is no information available regarding any feedback from passengers, since the new buses were only put in service recently. The operator's responsibility includes deployment of the ramp, assisting in the deployment of retractable belts if requested, fare collection and ensuring that the passenger in a wheelchair is positioned in the compartment. Trials are presently underway to determine criteria for the type and size of wheelchairs/scooters that can be accommodated in these new buses.

4.5 Montreal
In September 2000, the STCUM in Montreal will be operating 368 low floor 12 m Nova LFS buses.

Equipment
All Nova LFS buses are equipped with one rear facing wheelchair position curb side near the centre door. The general seat lay-out from front to centre door is comprised of double seats curb side and single seats roadside. A sliding ramp at the centre door provides access for passengers using wheelchairs. The rear facing position is equipped with a fixed back/head panel and an aisle stanchion. There is a three seat flip up bench in the compartment with seats in the down position when no wheelchair passenger is onboard. The compartment area is clearly marked on the floor with bright stripes, the wheelchair symbol and the words " ZONE RESERVE". A separate stop request is located in the compartment, and an electronic sign indicating "Next Stop" on both sides is mounted on the

ceiling in view for the rear facing passenger. A separate courtesy seat facing the operator is located just behind the front door with a large yellow pictogram indicating the priority for persons with reduced mobility, e.g. elderly, disabled, and pregnant women.

Operation

Approximately 1 to 2 passengers in wheelchairs per day (15 - 20 per week) are transported on 7 accessible routes. At each of the stops on the route, a display panel with either a blue or orange wheelchair symbol is mounted for the benefit of the operator: blue indicates kneeling is required for stops with a low curb height, orange indicates that kneeling is not required because of a high curb. One of the major obstacles to make all routes accessible is the infrastructure. Many bus stops need refurbishing or relocation. The operator's responsibility includes kneeling the bus, ramp deployment, vacating seats in the wheelchair compartment and ensuring that the passenger faces to the rear. He/she is not responsible to assist in boarding/exiting unless of his/her good will. Fare collection is through a honour system or for regular passengers using passes. Boarding time for wheelchairs is between 30 - 45 seconds. Passengers using the rear facing position would like to face forward like anybody else, but have accepted the rear facing position due to their increased independence. The biggest problem for the operator is to make other passengers vacate seats in the compartment area. No accidents with passengers using wheelchairs in the rear facing position have been reported. If passengers cannot board alone, or if their wheelchair/scooter type cannot be accommodated, the operator calls the paratransit system.

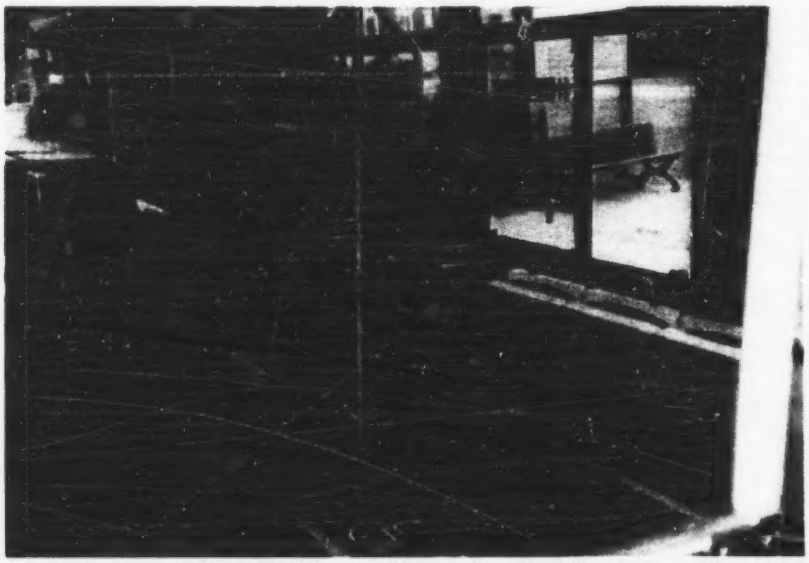

Fig. 12 Single rear facing position with aisle stanchion and marked floor area on Nova LFS buses used in Montreal by the STCUM

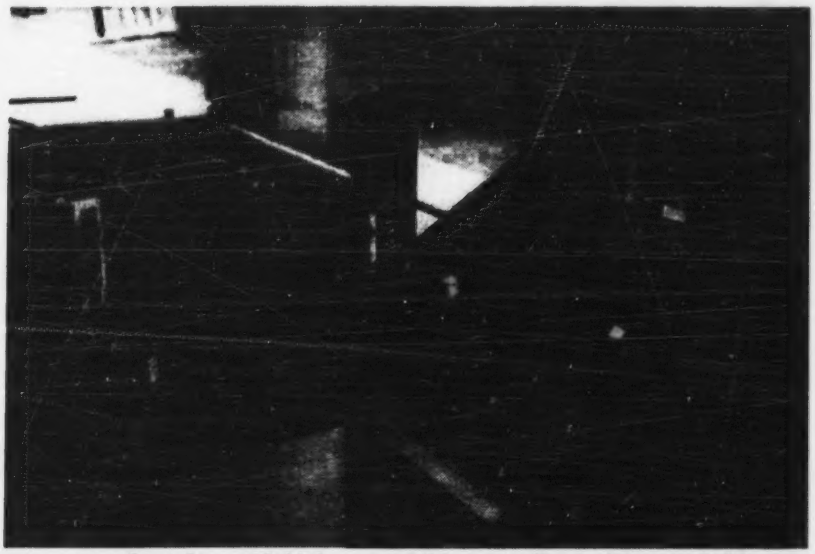

Fig. 13 Courtesy seat at front door with high contrast (blue on yellow) pictogram in Nova Bus in Montreal

Preliminary feed-back from operators seems to indicate the following advantages:

- Boarding of the general public can take place at the same time at the front door while boarding/alighting of the wheelchair passenger at the centre door, thus reducing dwell times.
- The wheelchair passenger is not occupying the crowded front section of the bus while manoeuvring. This also allows for the designation of priority seats in the front section.
- The wheelchair positions can be located near the centre door, thus requiring a short path from the entrance to the location.
- Wheelchair passengers can board facing front or back due to the short distance to the wheelchair position.

The disadvantages of boarding through the centre door seem to be:

- The operator does not have a direct view of the operation and relies on mirrors or other devices to observe the boarding and alighting of the wheelchair passenger.
- The operator may have difficulties aligning the centre door with the wheelchair landing on the platform.
- Provision must be made to carry out fare payment near the centre door, or the operator must come to the wheelchair passenger for payment.
- For the safety of passengers, the centre door must be closed while the ramp is deployed or retracted (in case of a telescopic ramp).

5. IMPLEMENTATION ISSUES

A number of implementation issues have been identified as part of this research. They include:

- vehicle design,
- wheelchair manoeuvrability, placement, and securement
- operator training, and
- standards development.

5.1 Vehicle design

Low floor buses come in three basis sizes:
i) standard transit buses, 9.3 m (30 feet), 10.8 m (35 feet) and 12 m (40 feet) long with two axles;
ii) articulated buses, 18 m (60 feet long) with three axles; and
iii) small buses, 6.5 m (22 feet) and 9 m (29 feet) long with two axles.

Standard and articulated buses are 2.50 m to 2.60 m (98 inches to 102 inches) wide and 3.04 m (120 inches) high.

Most low-floor buses have rear-mounted drive lines. Standard buses have 2 or 3 doors, each 1250 mm (48 inches) wide; articulated buses have 3 to 4 doors. Door locations are front, ahead of the front axle; centre, before the rear axles; and rear (optional), behind the rear axle (Orion VI, 1997).

Relevant vehicle design accessibility components include service door dimensions and locations, seating capacity, seating layout and orientation, floor level design, stanchion position, and locations for mobility aids.

One of the main issues with accessible low-floor buses is the reduced seating capacity. Standard high-floor transit buses have 45 seats. Accessible low-floor buses have 32-35, because space must be made available for the two wheelchair positions and some seats must be oriented sideways to make room for wheelchairs to manoeuvre. Many transit systems provide aisle facing seats in wheelchair locations, which can create another problem. A minimum lateral clearance of 750 mm is required for a wheelchair between the stanchion and the wall or seats. If seats in the up position take up too much space the lateral distance for the stanchion moves it into the aisle, thus creating a reduced aisle path for other passengers. Some bus transit systems use the 2 and 1 seat lay-out to increase manoeuvring room for passengers in wheelchairs and capacity for standees.

Interior design issues include the placement and design of stanchions for the general public and for wheelchair locations. These issues are discussed further in the section on wheelchair placement and securement.

Low-floor designs are of two types: (i) a flat, low floor from the front door to just behind the centre door, with a raised section behind the centre, accessed by two steps; and (ii) a flat, low floor from front to rear, with a ramp over the rear axle, without steps. The latter design requires seats in the rear section

to be placed on platforms or pedestals. Since passengers must step up to these seats, this section is inaccessible to many persons with physical disabilities.

5.2 Wheelchair manoeuvrability, placement, and securement

The five basic types of wheelchairs range from self-propelled lightweight models to larger, heavier, powered wheelchairs and scooters. Most wheelchairs in the marketplace today have not been designed and tested for use as seats in motor vehicles. In addition, many of the newer frame and lower shroud designs make it extremely difficult to locate suitable points for the securement of a wheelchair in a motor vehicle. The variety of wheelchair base designs make it also difficult to standardise a securement method.

Progress is being made in both standards development and testing of wheelchairs, with a view to designating attachment points for securement on wheelchairs designed to be used as seats in motor vehicles. However, many designs will still not be certified, or suitable for certification, in the near future. Achieving certification for all basic designs will likely take 5 to 10 years.

Control technology is advancing, especially since the adoption of microprocessors. As a result, more people with severe motor deficiencies are now able to control powered wheelchairs themselves and can use transit services independently, without an attendant.

Manoeuvrability

Manoeuvrability issues include: the size, design, and turning radius of wheelchairs and scooters; the seat lay-out of the bus; the location of the service door for wheelchair boarding and alighting; the location and orientation of the wheelchair position; the location and number of fixed stanchions; and the impact of wheelchair manoeuvres on other passengers.

Three wheelchair dimensions are critical for assessing public transit buses: length, width, and turning radius. Only a few wheelchairs have widths in excess of 660 mm (26 inches). However, an additional clearance of 50 mm (2 inches) is required on each side of the wheelchair for hands to manoeuvre manual wheelchairs, thus requiring an aisle and door width of a minimum of 762 mm (30 inches). In most urban buses, a mobility aid of more than 1,20 m (48 inches) in length, and a turning radius of more than 1,00 m (39 inches) cannot turn into the aisle.

Urban transit bus doors have at least a 815 mm (32 inches) clear opening and a ramp or lift width of 762 mm (30 inches). In the United States under ADA, bus lifts and ramps must be designed for a maximum weight (occupant and wheelchair) of 600 lb.

Placement

Placement issues include: the number of wheelchair positions per bus; front versus centre placement; staggered, opposite or tandem positioning; wheelchair passenger profile; use and location of entrance and exit doors; and the effect on other passengers.

The number of positions for wheelchair users varies. In Germany, buses have only one position; in the United Kingdom and France, one or two positions are used; and in the USA, two positions are required.

In Europe, wheelchair positions are usually near or opposite the centre door, which is where passengers in wheelchairs board and alight. In North America, positions can be at the front of the bus, behind the wheelwells, when the front door is used for boarding and alighting, or near the centre when the centre door is used. Wheelchair positions are used in tandem, opposite, and in staggered lay-outs.

The wheelchair passenger profile in Europe differs from that in North America. In Europe, most passengers use a manual or sports wheelchair when travelling on a bus; fewer passengers with electric or power chairs use the bus. In North America, three-wheel scooters and electric power chairs are more widely used. In Canada and the Northern United States, where inclement weather prevails, wheelchair users are heavily dressed in winter and often carry front and/or rear bags or baskets on their wheelchairs, thus increasing the dimensions required to manoeuvre within the bus.

One of the key issues in accommodating wheelchair users on low-floor transit vehicles is ensuring that the doors and interior layout are adequate to accommodate the many wheelchair designs on the market. Trends in wheelchair design and particularly in control systems for motorised wheelchairs are important, especially from the perspective of designing suitable securement systems on board buses to accommodate the variety of sizes and designs of wheelchairs and scooters. Standardising the length, the width and the turning radius of wheelchairs and scooters may help passengers using wheelchairs as well as the transit systems.

Wheelchair Securement

Securement issues include: forward versus rear facing of wheelchair passengers; independent or assisted use of securements; desired level of safety, especially in comparison to levels offered other bus passengers; and adaptation for different wheelchair sizes and designs.

Two alternatives have come to the forefront for the securement of wheelchair passengers on transit buses: a forward facing orientation and a rear facing orientation.

Forward Facing Securement

The system consists of two components: the wheelchair securement and the occupant restraint. In the forward facing position the wheelchair is required to be secured to the vehicle similar to a bus seat, involving typically 4 separate belts to meet ADA requirements. The occupant restraint requires a lap and a shoulder belt. The wheelchair user typically accesses the bus through the front door, and must turn 180 degrees to face the front of the vehicle. In most low-floor buses, wheelchair positions are located immediately behind the front wheels.

In Canada, variations of the forward facing system have been used. The wheelchair is either secured by two rear belts only, with a scooter requiring an additional front belt, or a combination of wheel rim lock with retractable rear belt. An occupant restraint is available in many transit vehicles, but its use is not mandatory.

Alternative securement systems using other mechanical concepts have been, or are being, researched in the hope of developing a universal securement system(e.g., a docking system, the Cleveland Clinic harness). However, they have not yet proven effective, largely because of the wide range of wheelchair designs, and/or the modifications that are required for mobility aids, which users dislike.

Implementation issues include: who deploys the system; logistics and cost of service; maintenance and storage of belts; the adaptation of the system to different wheelchair types and sizes; the use of the front or centre door; the effects on other passengers; the fare payment method; the manoeuvrability; seating lay-outs; and passenger's human factors. This last factor is of particular importance. Forward facing securement, whether in its 4 belt ADA version, or even in the modified 2 belt typical Canadian version, is extremely awkward. Both bus operators and wheelchair passengers complain of the physical discomfort caused by the close and intrusive physical contact required for securing the belts, around and across the wheelchair. Wheelchair passengers sometimes view it as degrading, especially as it emphasises the special treatment they require. It is an inherent problem with forward facing securement designs.

Rear Facing Position

This system requires no wheelchair securement or occupant restraint, and no assistance from other persons in most cases. The wheelchair passenger faces the rear, and forward movement of both the wheelchair and the user is constrained by the back panel. Locations of the rear facing system can be at the front or near the centre door, depending on which door is used for boarding and alighting. It does not secure the wheelchair as if it were a bus seat but offers great independence to the wheelchair passenger, while reducing the involvement of the bus operator. As a result, it has been implemented, as previously discussed, by several Canadian transit systems as a possible alternative to the existing, forward facing systems.

Implementation issues include the size and location of the position; the use of flip seats in the area and their natural position (e.g. up or down); a method to prevent mobility aids from moving/tipping into the aisle; means to provide visual and audio information for the next stop to rear facing passengers; and the problem of motion sickness experienced by some passengers when facing to the rear.

5.3 Operator training

Operator awareness and training are important factors if a system is to be successful. This includes: attitudes when wheelchair passengers are on board; the need to respond to stop requests from wheelchair passengers; assistance in vacating seats in wheelchair locations; keeling of the bus; the proper operation of the ramp for boarding/alighting; the need to ensure that wheelchair passengers face to the rear in the rear facing position; and approaching the bus stop platform to board or alight wheelchair passengers at the designated landing area with the vehicle parked close and parallel to the curb.

5.4 Standards development

In Canada, the CAN/CSA D409-92 standard was developed to protect passengers using mobility aids when being transported in small vans, and special paratransit vehicles. However the introduction of low floor buses in urban transit has enhanced the ability to make public transit accessible for persons with

mobility impairments and in particular to persons using mobility aids. This raises the issue of standards in Canada. Revisions have been proposed to D 409, for large transit buses in June of 2000. The proposals made in this document are based on present practice and the previously discussed research which has been undertaken in Germany, the UK and Canada in the last decade. This research suggests:

- That G forces on large transit buses with a GVWR of 7,000 kg or over are much smaller than on lighter vehicles (e.g. small buses, vans, special vehicles), due to larger masses and lower operating speeds;
- That on large transit buses, mobility aid users can travel safely in the rearward facing position without securement systems provided that adequate provision is made for the location and positioning of their mobility aids, and
- That this standard is further supported by evidence from transit operators on how well the practices have worked on large accessible transit buses both in Europe and in Canada

Excerpts of proposed revisions relevant to the Occupant Safety in Large Accessible Transit buses include:

- definition of large accessible transit buses
- mobility aids to face forward or rearward
- floor space for mobility aids
- securement devices
- mobility aid securements and occupant restraint components
- interior pathway dimensions
- entrance door dimensions and operation for loading and unloading passengers in mobility aids
- contrasting colour stripes for steps and floor surfaces
- riser design
- lamps at front door and centre/rear passenger doorways
- seat and seat pitch dimensions
- grab bars, handholds and stanchion dimensions and locations
- folding seats
- lift and ramp specifications

It is anticipated that the new standard for large accessible urban transit buses will be completed by the CSA D409 Committee by early 2001.

6. REQUIREMENTS & CONCEPTUAL DESIGN CONSIDERATIONS

The following requirements are suggestions proposed by the consultant based on the review of experiences with low floor buses and securement systems in Canada and European countries. They should be taken into consideration by transit systems in order to enhance accessibility by wheelchair passengers.

6.1 Operator requirements

It is essential that operators who operate accessible low floor buses be trained to be aware of the different requirements of mobility impaired passengers, in particular of those who use a mobility aid. The operator's responsibility could include the following:

- he/she drives more carefully, especially when braking or cornering, when passengers in wheelchairs are onboard,
- the operator does not start moving the bus before ensuring that the passenger in a wheelchair is safely accommodated in the position,
- other passengers occupying the seats in the wheelchair position vacate these seats when a wheelchair passenger is boarding,
- the operator approaches the curb in a way to secure a parallel line-up when a passenger in a wheelchair is boarding or alighting,
- the operator tries to line up the service door position with the designated landing area for the wheelchair on the bus platform,
- the operator is alerted by a separate stop request signal from the wheelchair position(s).

6.2 Requirements - front boarding

The requirements for front boarding could include that:

- the operator must have an unobstructed direct view from his position to observe the ramp deployment and wheelchair boarding and alighting,
- the front door must be wide enough to accommodate commonly used wheelchairs and scooters
- the ramp must be located at the front door,
- the ramp be wide enough to accommodate commonly used wheelchairs and scooters,
- the ramp slope to the road, when the bus is kneeled, should not be less than 1:4,
- the operator can operate the ramp from his/her position,
- a clear floor area from the door into the aisle be available for a 90 degree turn with commonly used wheelchairs or scooters,
- for front facing wheelchair positions there is sufficient floor space to turn the mobility aid 180 degrees and back into position, (including floor space under seats overlapping mobility aids manoeuvring space),
- for front facing securement, assistance must be available to deploy and disconnect securement components,
- for rear facing positions, there must be enough floor space to back into the position and do a 180 degree turn when exiting, (including floor space under seats overlapping mobility aids manoeuvring space),
- for rear facing positions, a method be designed to prevent the mobility aids from sliding or tipping into the aisle,

- for rear facing positions, a visual and audio system related to the next stop information be made available.

6.3 Requirements - centre boarding

The requirements for centre boarding could include the following:

- the operator have an unobstructed view to the outside interface between the bus and the stop platform, the ramp deployment and the centre door,
- the centre door be wide enough to accommodate commonly used wheelchairs and scooters
- the ramp be located at the centre door,
- the ramp operation be controlled from the operator's station,
- there is an unobstructed floor area from the centre door to the wheelchair position to accommodate most commonly used wheelchairs and scooters,
- there is a satisfactory fare payment method in place for passengers boarding through the centre door,
- for the forward facing position, there is sufficient floor space to allow commonly used wheelchairs and scooters to manoeuvre into position (including overlapping floor space under other seats), and to allow for a 180 degree turn when exiting,
- for front facing securement, assistance must be available to deploy and disconnects securement components,
- for rear facing positions, there is enough floor space to back into the position and do a 90 degree turn when exiting, (including floor space under seats overlapping mobility aids manoeuvring space),
- for rear facing positions, a method be designed to prevent the mobility aids from sliding or tipping into the aisle,
- for rear facing positions a visual and audio system related to next stop information be made available.

6.4 Conceptual design

Based on the requirements from the previous sections, a preliminary design has been developed which is shown with its main elements and dimensions in the following drawing. The " Rear Facing Design Position" is a configuration with the wheelchair user facing the rear of the bus. It does not require a wheelchair securement or passenger restraint. The proposed conceptual design is considered by several Canadian transit operators who are implementing the system and using a variety of position configurations.

For the wheelchair passenger in the rear facing position the following elements are required:

- a rectangular floor space
- a load bearing back and headrest
- a vertical aisle stanchion, wall mounted lateral belts or other means to prevent the wheelchair scooter from sliding or tipping into the aisle
- an accessible path from the service door to the wheelchair position, and floor space to manoeuvre into and out of the position
- a horizontal handrail along the bus wall

- a stop request button with a separate signal displayed at the operator's workstation
- a visual stop display that can be seen by the wheelchair passenger

Rectangular floor space
A rectangular floor space of 1500 mm in length is required measured from the front of the back rest, with a width of 750 mm. The space is located with the long dimension along the bus wall. These dimensions should be considered clear of any other fittings within this area, e.g. flip up seats in their stored position (see Figs. 14 and 15).

Load bearing back and head rest
A load bearing head/back rest is to be positioned centred in the transverse direction. The padded panel should be fixed to the vehicle withstanding the same forces as a regular bus seat. It should be 300 mm wide, 1300 mm high and have a floor clearance of 350 - 480 mm. There should be a clearance of about 300 mm behind the back panel to prevent large rear wheels from contacting any obstacle before the passengers makes contact with his/her back to the panel. The lower part of the panel structure should be designed in a way to prevent batteries from sliding beyond the structure in a severe deceleration.

Vertical aisle stanchion
A fixed vertical aisle stanchion or other means of preventing the wheelchair from moving into the aisle is required when cornering. Because in North America a large percentage of scooters are used, and are often outfitted with rear baskets, the longitudinal dimension of the stanchion position from the front of the back panel is critical. If the dimension is too short it will not prevent the wheelchair from moving into the aisle, if it is too long it makes manoeuvring of the wheelchair into the position difficult. Present experience suggests a dimension of approximately 500 mm.

Diagonal Clearance
A diagonal clearance of about 1000 mm between the stanchion and the rear bulkhead should be available. This is one of the most critical dimensions for the wheelchair to be able to back into position against the panel. The shorter the transverse dimension of the bulkhead the easier it is for the wheelchair passenger to get in and out of the position, especially for scooters with larger turning radii. Manual, sport chairs and electric power chairs have relatively short turning radii and can cope with shorter clearances, scooters can not (see Figs. 14 and 15).

Horizontal handrail
A horizontal handrail of at least 800 mm in length at waist height along the bus wall is required for a wheelchair passengers to hold onto.

Stop request button
A stop request button should be available in the wheelchair space within easy reach for the passenger and give a separate signal for the operator.

Stop display

A visual stop display should be within direct view of the wheelchair passenger displaying the message in text or pictogram mode. The same should apply for all other rear facing passengers who can not see the upcoming stop.

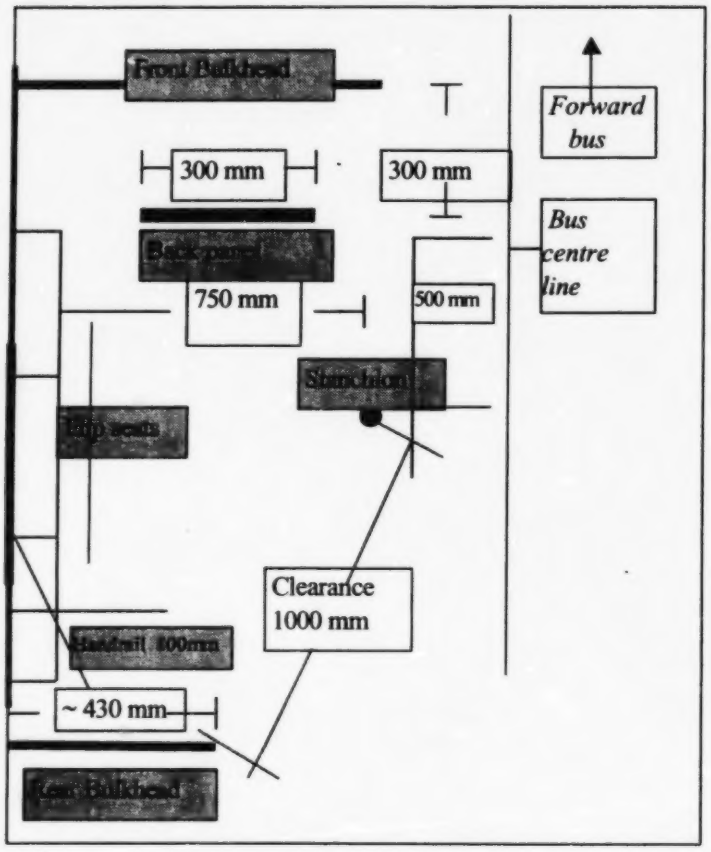

Fig. 14 Rear facing position design, recommended geometry - top view

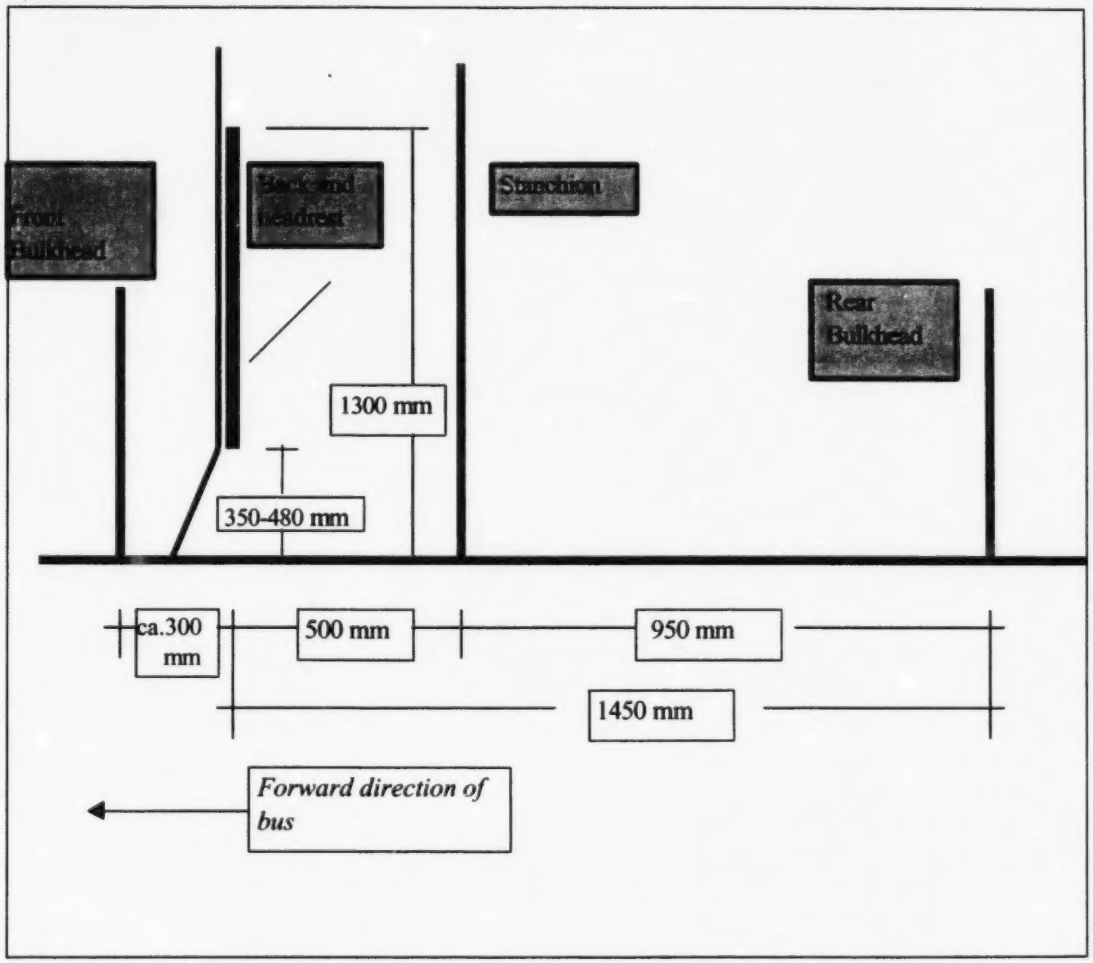

Fig. 15 Rear facing position design, recommended geometry - lateral view

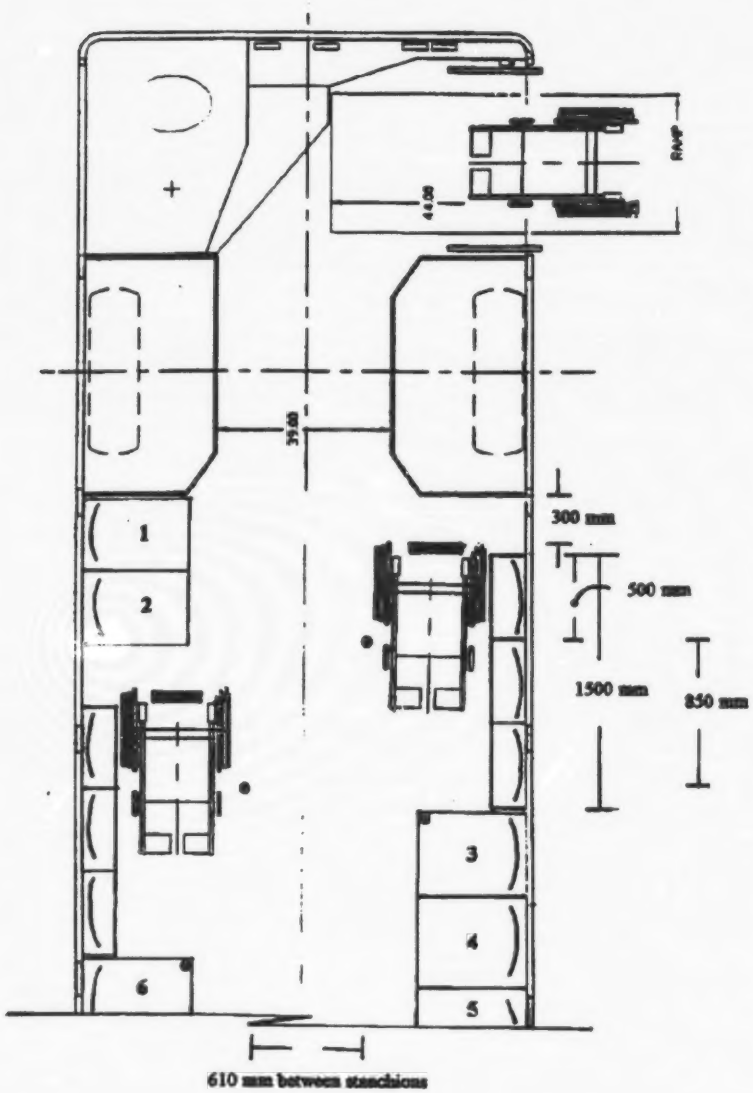

Fig. 16 Front door boarding and alighting - two staggered rear facing wheelchair positions

- Staggered stanchions allow for better manoeuvring in and out of positions
- Foot clearance under seats 3 and 6 required
- Passengers in seats 1 and 2 may have to get up for wheelchair manoeuvres
- 3 flip seats in every wheelchair location

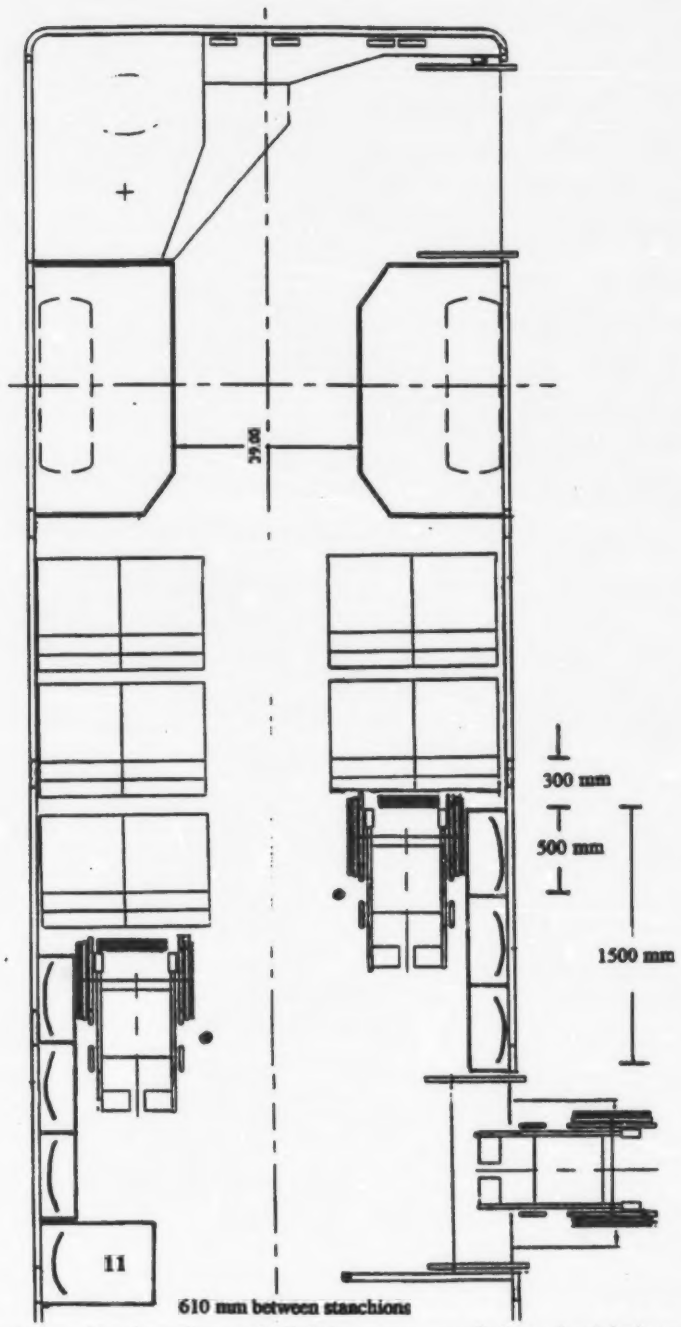

Fig. 17 Centre door boarding and alighting - two rear facing wheelchair positions

- Passenger in seat 11 may have to get up for wheelchair manoeuvres
- Foot clearance under seat 11 required
- Staggered aisle stanchions allow for easier manoeuvres of wheelchairs

6.5 Analysis front versus centre boarding

In Canada two transit systems have implemented boarding and alighting of wheelchair passengers using the centre door, Hamilton's HSR, and Montreal's STCUM. Hamilton is using a flip ramp at centre door, the operator must get up from the station and operate (deploy and retract) the ramp using a control at centre door stanchion. Montreal is using a telescopic ramp at the centre door. Preliminary results indicate that boarding and alighting of persons using wheelchairs does not present conflict when other passengers are boarding, the wheelchair positions can be located closer to the service door and the path from door to position is short.

Operators in Ottawa, Victoria and Grand River Transit are using the front door with a flip ramp for boarding and alighting. Initial results indicate that the operator has a direct view of the operation, fare payments are carried out at the operator's station, and the flip ramp has the advantage that it can be used manually should the hydraulic fail. The front door is easier to line up with the wheelchair landing of the bus stop platform when approaching the curb. The wheelchair positions are located behind the wheelwells and therefore require a long path from door to wheelchair position, crowding the front end of the bus which is typically the busiest.

The following table represents an analysis of boarding design options. The results are theoretical and based on simulations on drawings.

Table 2 Comparison front versus centre boarding & alighting

	FRONT DOOR ACCESS		CENTRE DOOR ACCESS	
	Rear facing position Road side	**Rear facing position Curb side**	**Rear facing position Road side**	**Rear facing position Curb side**
BOARDING				
Ramp request	not required	not required	alerting operator and/or outside control	alerting operator and/or outside control
Ramp operation	by operator from workstation	by operator from workstation	by operator from workstation	by operator from workstation
Manual ramp back-up	by operator - flipping	by operator - flipping	NOT DETERMINED	NOT DETERMINED
Fare payment	at operator's workstation	at operator's workstation	NOT DETERMINED	NOT DETERMINED
Turns required by wch. user	(3) 90 degrees	(3) 90 degrees	(1) 90 degrees	(3) 45 degrees
Conflict areas	Pass. # 1,2,3,4,	same on opposite	NONE	Seated pass. must get up
Operator's visual control	direct, from workstation	direct, from workstation	indirect, mirrors/video	indirect, mirrors/video
General public	enter front door	enter front door	enter front door	enter front door
ALIGHTING				
Stop request by whch. user	push button/strip	push button/strip	push button/strip	push button/strip
Stop display	required at centre/ rear	required at centre/rear	required at rear	required at rear
Turns required by whch. user	(3) 90 degrees	(3) 90 degrees	(1) 90 degrees	(3) 45 degrees
Conflict areas	Pass. 1,2,3,4	same on opposite side	NONE	NONE
Operator's visual control	direct, from station	direct, from station	indirect, mirrors/video	indirect, mirrors/video
General public	most exit at centre door	most exit at centre door	most exit at centre door	most exit at centre door

6.5 Design Options

Design options include the following main components:

1. Front door or centre door boarding/alighting,
2. Forward or rear facing orientation of wheelchair passenger, and
3. Wheelchair position configurations.

Front door or centre door boarding/alighting

Depending on the operation, the infrastructure and the service policy, either the front or the centre door are options for boarding/alighting a passenger in a wheelchair/scooter. Although there are bus models with a rear door (e.g. Orion VI), located behind the rear axle, this door cannot be used with a ramp since the bus floor is elevated to accommodate the drive train location.

Forward or rear facing orientation of wheelchair passenger

In low floor buses two approaches for design options have come to the forefront; the forward facing and the facing positions. These options have been illustrated and described in previous sections.

For the forward facing approach there are several options;

1. Four point (ADA) system
2. Two belt with wheel stop system (Victoria)
3. Wheel Rim lock combined with retractable rear belt

For the rear facing system there is one typical design with several options for its components. The back panel is a load bearing component in a vertical or slightly inclined position to contact with the passengers back and head. Within the area for the wheelchair three options for seats are available, (i) no seats, (ii)flip up seats or bench along the bus wall, (iii) or one flip seat combined with the back panel. To prevent the wheelchair/scooter from sliding/tipping into the aisle, a fixed aisle stanchion, or a wall mounted lateral belt are options.

Wheelchair position configurations

Wheelchair configurations depend on the seat lay-out and seat capacity, the choice of the service door, and the wheelchair orientation. Options for wheelchair configurations include tandem positions at curb side, tandem positions at road side, two staggered positions opposite, two non-staggered opposite positions, or one position only at curb or road side.

6.7 Combi design concept

In addition to the previous wheelchair orientation options (forward and rear facing) a third option might be a design combining both rear and forward facing design. One of the issues which has come up among wheelchair users in Canada is to have a choice of facing front or rear in a bus. Earlier results with rear facing positions in Hamilton have shown that operators do not always insist that wheelchair passengers face rear, thus defeating the safety purpose of the system. Some wheelchair passengers do

not realise that they have to face to the rear despite text and pictograms provided. Some ignore the fact that they have to face the rear in the rear facing position and others would just prefer to face forward. Based on these observations, consideration has been given to the concept of a "Combi Design", a wheelchair position in the bus which is equipped for both forward and rear facing wheelchair passengers. This concept is presently planned for implementation in BC Transit's double-decker low floor buses in Victoria.

The following are preliminary requirements that have been developed for this study, but would need to be verified with the stakeholders, e.g. wheelchair passengers, transit operators, and bus manufacturers. Dimensions are estimated; it should be noted that estimates assure that either the rear or forward facing position is selected by the wheelchair passenger. The design does not accommodate 2 wheelchairs.

Geometry:

The following factors are important for the geometry of a combined system:

- Floor area for both systems
- Rear facing back panel at front end of area
- Securement components for forward facing passengers on opposite end of back panel

Floor area

The clear length of the area between front of back panel and wheel stop, is estimated at about 1950 mm, taking into consideration that for the rear facing position the wheelchair needs a clearance of about 1000 mm to the stanchion and 500 mm between stanchion and the front of the back panel. For the forward position a minimum path length of 1397 mm is required to back against the securement. The width at the rear facing position between wall/flip seats and stanchion is 750 mm. The width at the forward facing position is about the same or slightly more, depending which securement type is used.

Rear facing back panel at front end

The rear facing back panel should be located at the front end of the area, centrally placed in the transverse direction. A fixed vertical stanchion or other means of preventing the wheelchair from moving into the aisle is required. A pictogram and text should be displayed in this area to inform the passenger in a wheelchair of the orientation options.

Front facing securement/restraint at rear end of area

A wheel stop with belts or other means of securement is required at the rear end of the area to secure the wheelchair to the vehicle, providing the same strength as for a regular bus seat. A front transverse belt is required for scooters. The securement components could be placed under a flip-up seat facing front.

Operational factors

If a choice is provided for the wheelchair passenger of using the forward facing position, assistance would be required to deploy and disconnect the securement and occupant restraint components. Storage of belts is typically the responsibility of the transit operator.

Location

The location and configuration of the Combi Design position(s) will depend on the service door designation used for boarding and alighting of wheelchair passengers, the position's lay-out, and the seating lay-out.

Conclusion

A concept combining forward and rear facing wheelchairs in one area seems feasible, pending tests to verify dimensions and operational issues. The advantages of such a design would be that persons who cannot travel facing rear and experience motion sickness would be able to face forward. The operator would not be required to insist on a certain orientation for the wheelchair user.

The disadvantage is that cleaning, maintenance and storage of belts or other components must be dealt with. The required floor area will be longer and new seat lay-outs must be verified.
The operator must make sure that in the forward position the securement is applied.

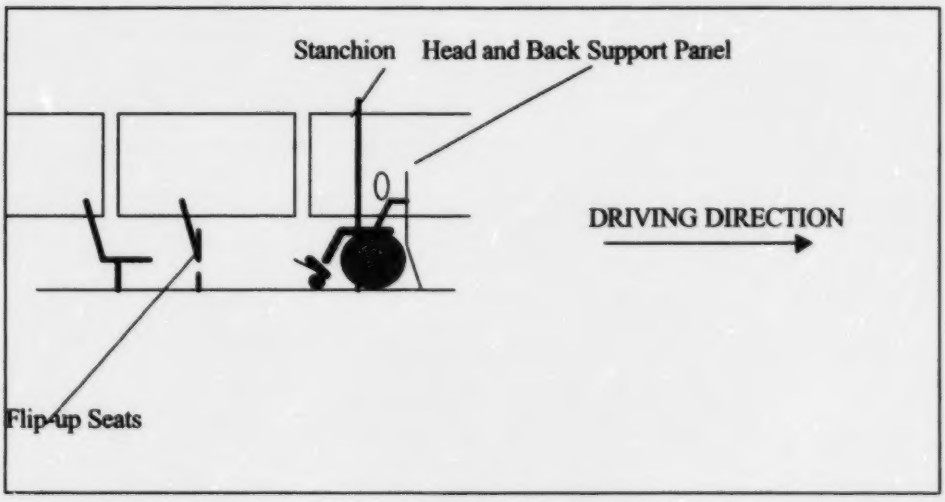

Fig. 18 Combi Design: Rear facing position

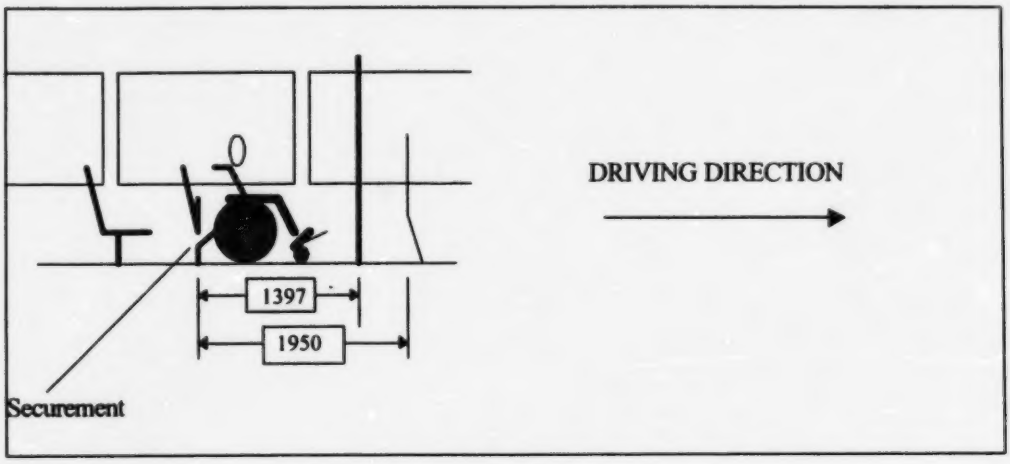

Fig. 19 Combi Design: Forward facing position

6.8 Templates

There are several issues to consider when developing templates for rear facing positions securements in a low floor bus:

1. Boarding and alighting at front or centre door
2. Seating lay-out (flip seats in wheelchair area)
3. Location of wheelchair positions (front or centre)
4. Wheelchair dimensions, floor area, paths

1. Boarding and alighting at front or centre door

Advantages and disadvantages of front or centre door use have been discussed in previous sections. In Canada climatic conditions, operator's view to observe wheelchair passenger entering and exiting, alignment of bus to curb and bus design (e.g. location of fuel tanks) determine which door to use.

2. Seating lay-out

In North America, the need to provide the maximum number of seats in a bus presents an important factor for a transit operator. Most places designated for wheelchairs in a low floor bus therefore use aisle-facing flip seats or benches. This can create a problem for the aisle stanchion in the wheelchair area, because 750 mm of clear transverse distance is required for the wheelchair. The more space a flip seat is taking up from the side of the bus, the more the stanchion must be moved into the aisle, thus reducing the aisle width for passenger flow. This may also require to stagger the wheelchair positions when they are located one on each side.

3. Location of wheelchair positions

Depending on which door is used for boarding and alighting, the positions for wheelchairs are typically located as close as possible to this door in order to reduce the length of the approach path.

4. Wheelchair dimensions, floor area and paths

There are several critical dimensions which determine access of wheelchairs when using a rear facing rear facing position securement: the wheelchair dimensions, the floor area, the approach and turning paths. In addition, some persons in wheelchairs may prefer to board backing in because of a shorter and easier access to the wheelchair position.

The following sketches demonstrate the critical factors. A wheelchair/ three wheel scooter with the following average dimensions has been used in these simulations, width: max. 700 mm, length: max. 1220 mm and a max. turning radius of 920 mm. Some electric wheelchairs, four wheel scooters or other special wheelchairs wider or longer may have difficulties accessing a low floor bus. Some users of wheelchairs may also lack the skills to manoeuvre their chair within the closed quarters of a transit bus.

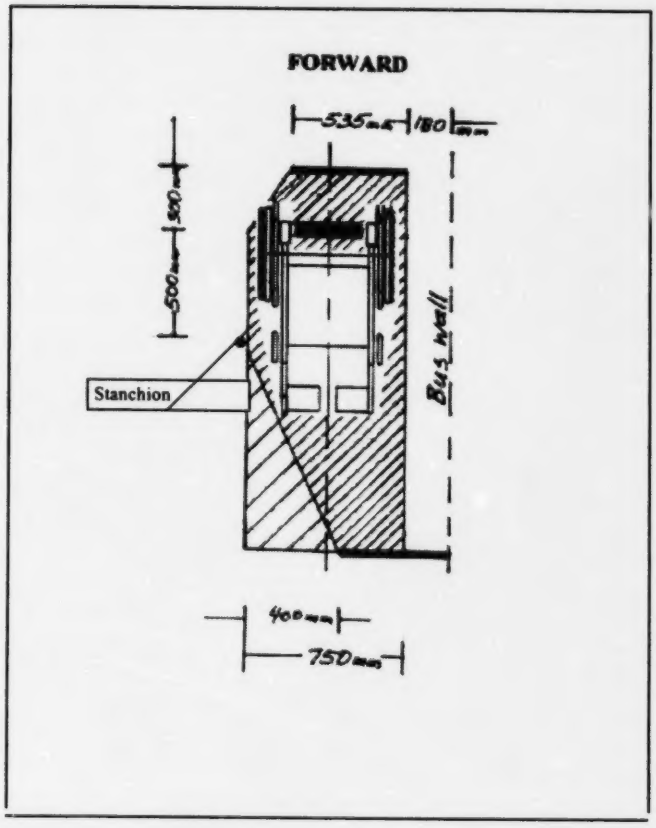

Fig. 20 Floor area required for rear facing rear facing position, curb side

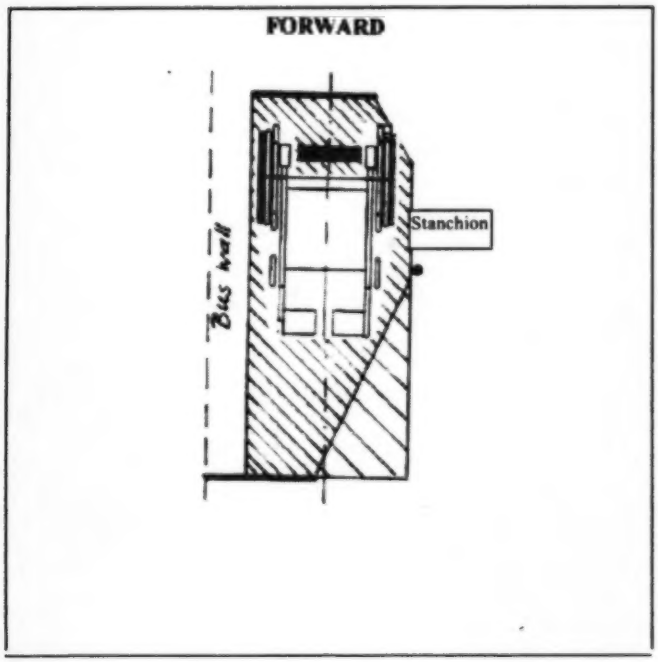

Fig. 21 Rear facing position, floor area at road side location

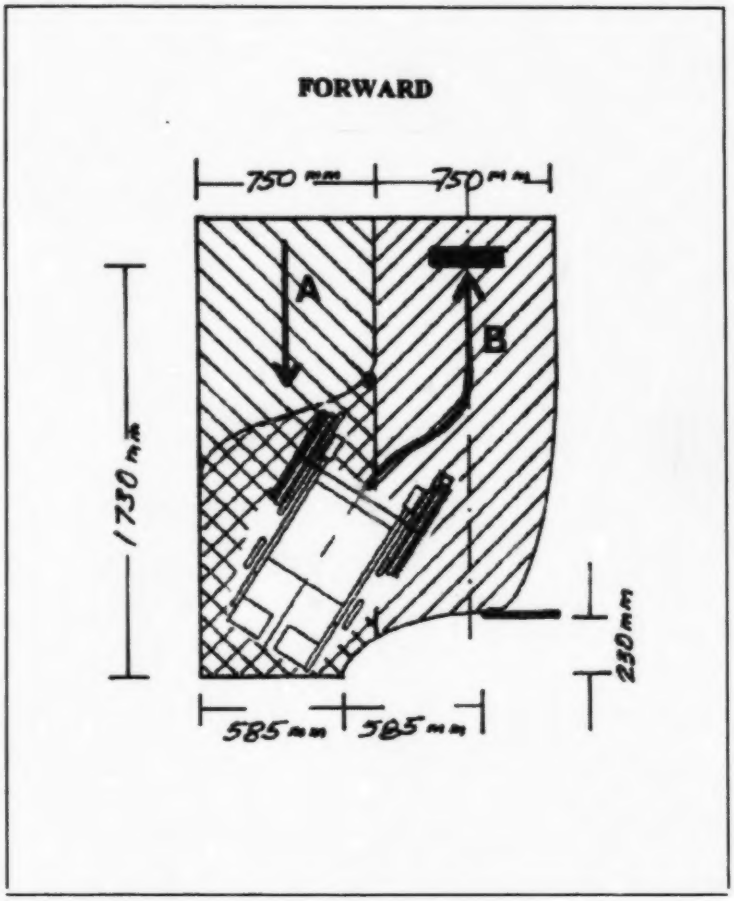

Fig. 22 Approach and path for rear facing position when using front door, curb side position

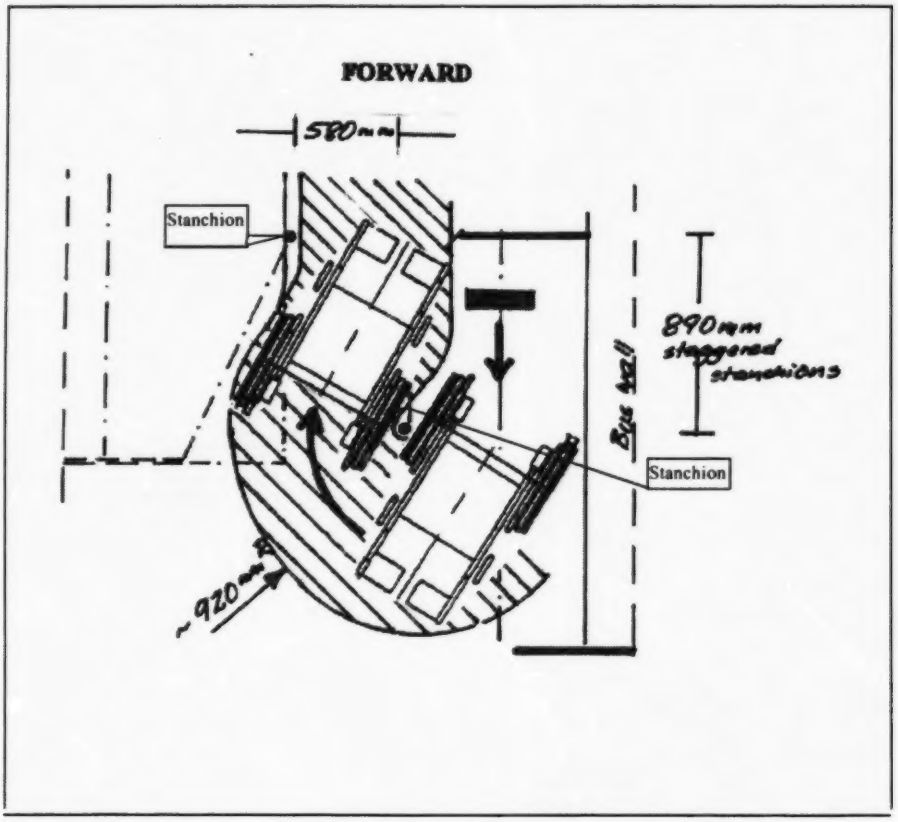

Fig. 23 180 degree turn for exiting rear facing position

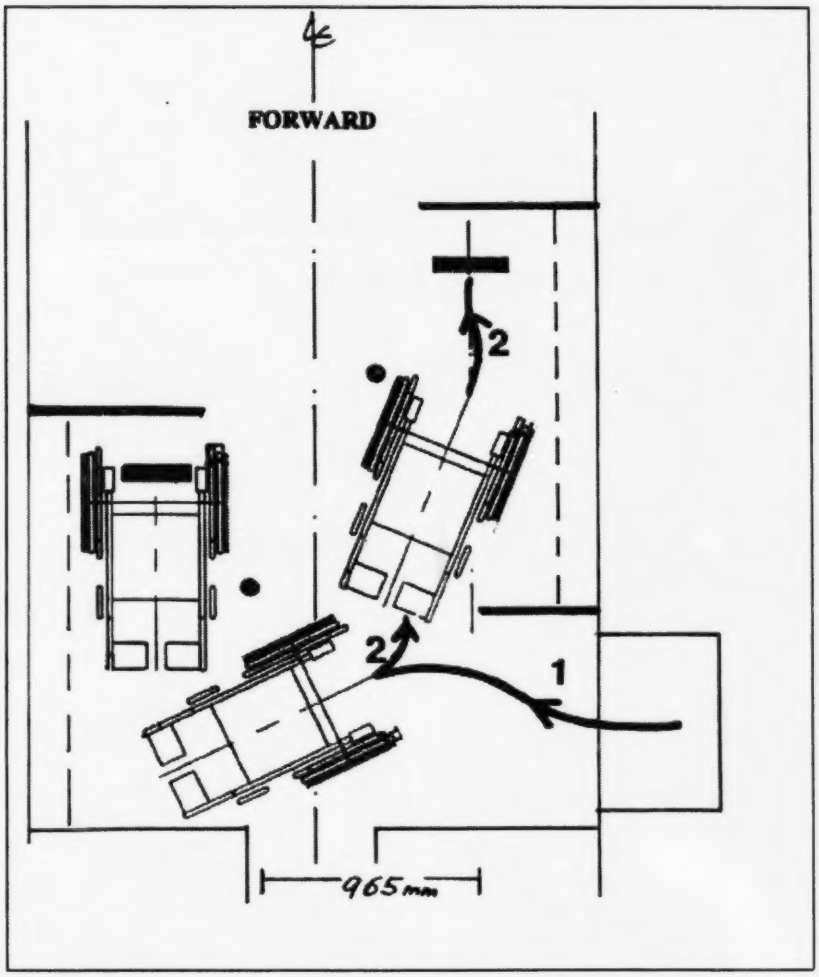

Fig. 24 Boarding front first through centre door into rear facing position at curb side with roadside position occupied

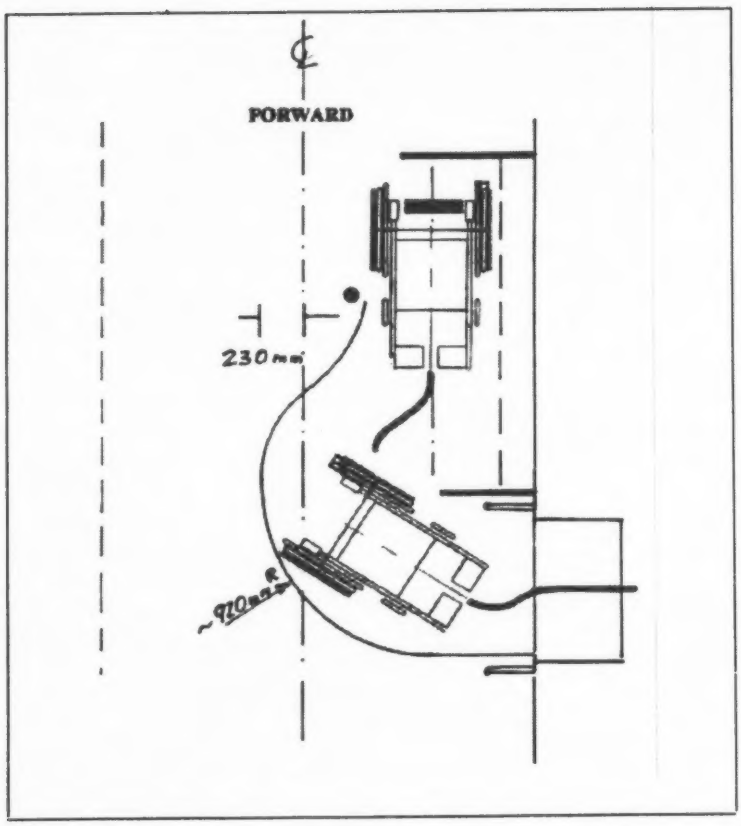

Fig. 25 90 degree turn: Boarding through centre door backing into rear facing side position, or alighting from rear facing position

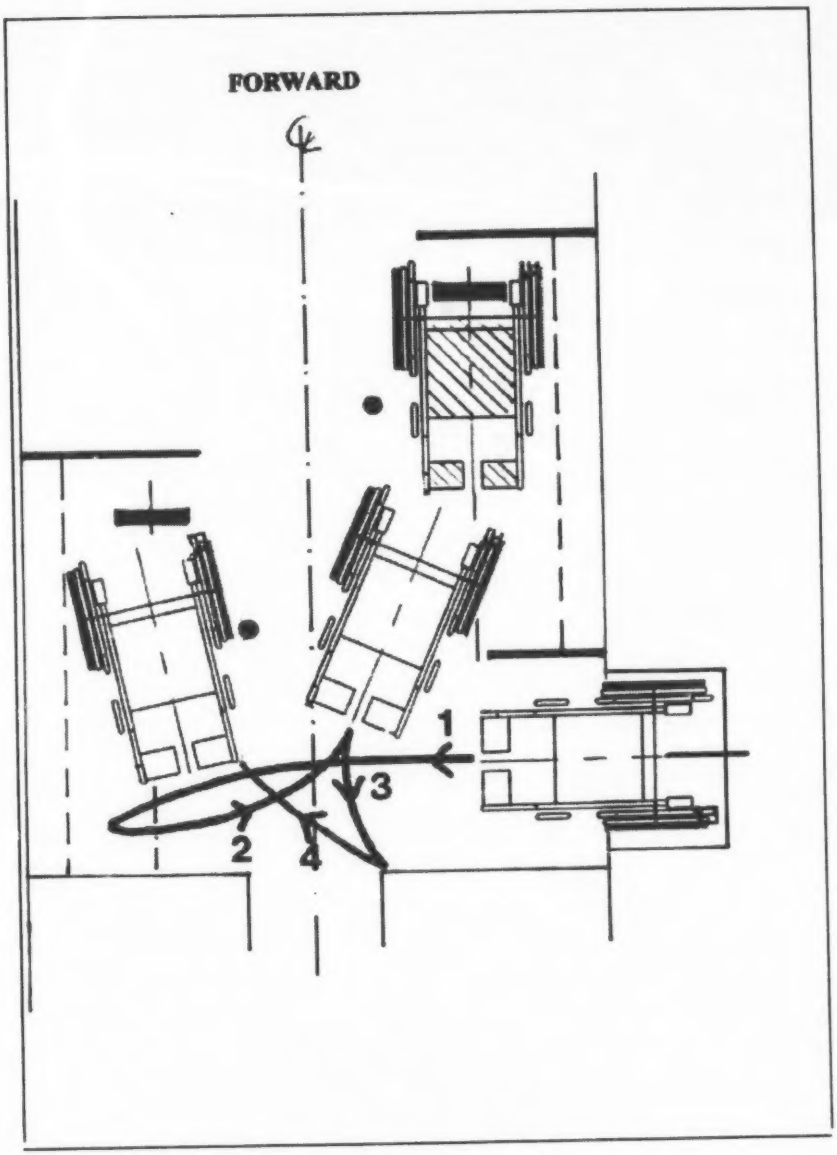

Fig. 26 Boarding through centre door into road side or curb side position

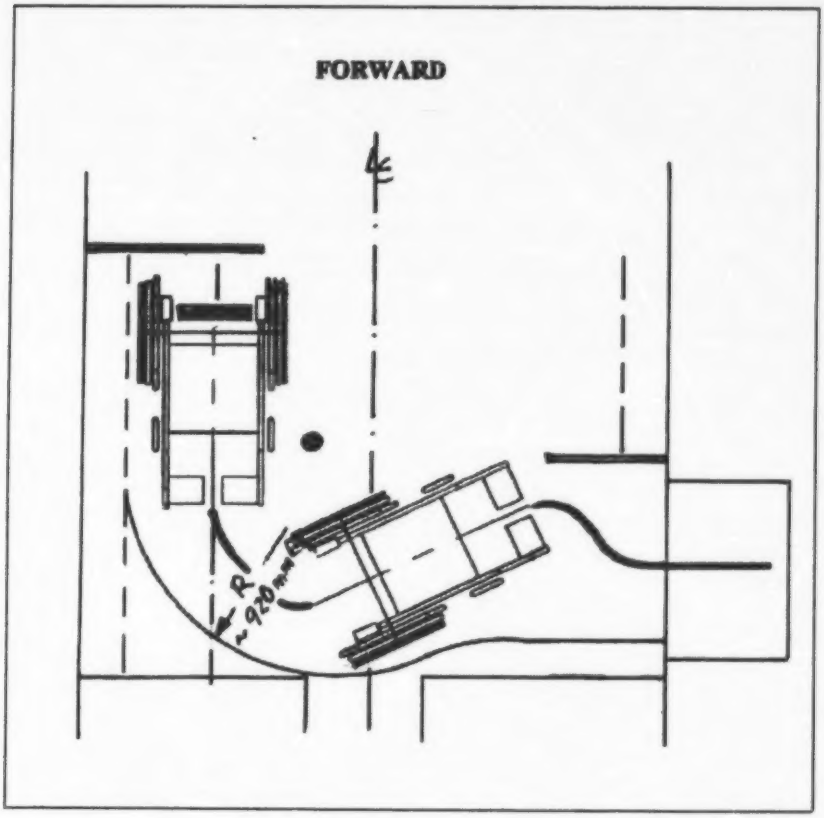

Fig. 27 Backing through centre door into rear facing position at road side

8. CONCLUSIONS AND FUTURE CHALLENGES

This review of research and considerable experience in European and Canadian transit systems, with the rear facing position for wheelchairs on large urban buses, has shown that there are many advantages to this approach, including:

- greatly expanded independence, enhanced dignity, and equal treatment for wheelchair passengers with other passengers,
- greater ability to accommodate most sizes and types of wheelchairs and scooters,
- reduced involvement by bus operators in boarding and securement of wheelchairs, which in turn reduces operator stress and potential injury,
- decreased boarding and dwell times,
- elimination of belt storage problem, and
- a higher level of safety offered to the wheelchair passenger than in a forward facing position when wheelchair is not secured.

Disadvantages include:

- the wheelchair passenger must face to the rear and has greater difficulty anticipating stops,
- in buses that have no other rear facing seats, the wheelchair passenger may dislike being the only one facing rear,
- the wheelchair's brakes must be applied to prevent movement when accelerating, or when on steep hills, and
- some wheelchair passengers may experience motion sickness in this position.

Most of all transit systems will need to assess the safety and liability issue. The rear facing design does not behave the same as a properly used forward facing 4 belt securement system, that essentially transforms the wheelchair into a vehicle seat; the wheelchair passenger is thereby offered a level of safety that far exceeds that of other passengers (e.g. seated frail persons or standees). Research and experience have lead many European and Canadian transit systems to conclude that the rear facing position provides an appropriate level of safety and is worth adopting given its many advantages. However this is an issue that each transit system will need to carefully consider from their own perspective.

Finally, this research of practices and experiences from Canadian and European transit systems has identified a number of challenges for the future, including areas for research and development:

- In providing complete accessibility for urban buses for people with mobility aids, the vehicle represents only one of the components. The other is the infrastructure, for instance bus stops, and the path to the bus stop, which must be equally accessible.
- It is important to provide a visual and audio message for the next stop for all passengers facing to the rear; better design should be developed.
- The combi design concept, involving a combined rear and forward position design, should be tested and evaluated.
- Operator awareness and training related to passengers using mobility aids is essential to provide safe and comfortable transportation, and should be enhanced.

- Information campaigns to promote awareness/sensitivity among other passengers need to be developed.
- For the longer term, designated attachment points on mobility aids should be developed by wheelchair manufacturers for the securement of wheelchairs and scooters in transportation vehicles. They should be highlighted with bright colours on the mobility aid.
- The design characteristics for transportable mobility aids should be standardised (length, width, turning radius, brakes, weight).

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